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IS 12641 (2004): Semiconductor Devices - Mechanical and Climatic Test Methods [LITD 5: Semiconductor and Other Electronic Components and Devices]



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Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

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भारतीय मानक
अर्द्धचालक युक्तियाँ — यांत्रिक एवं पर्यावरण कार्यविधियाँ
(पहला पुनरीक्षण)

Indian Standard
**SEMICONDUCTOR DEVICES — MECHANICAL AND
CLIMATIC TEST METHODS**
(First Revision)

ICS 31.080.01

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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NATIONAL FOREWORD

This Indian Standard (First Revision) which is identical with IEC 60749 (2002) 'Semiconductor devices — Mechanical and climatic test methods' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendations of the Semiconductor Devices and Integrated Circuits Sectional Committee and approval of the Electronics and Telecommunication Division Council.

At present following two Indian Standards exist on the subject:

IS 12641 : 1989 Environmental testing procedures for semiconductor devices and integrated circuits

IS 10477 : 1982 Environmental testing procedures for microcircuits

This standard has been prepared in order to revise above mentioned standards so as to align them with latest international practices. This standard constitutes the first revision of IS 12641. With the publication of this standard, IS 10477 shall be withdrawn.

The text of the IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

- a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.
- b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

Only the English text of the International Standard has been retained while adopting it as an Indian Standard, and as such the page numbers given here are not the same as in IEC Publication.

CROSS REFERENCES

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
IEC 68-1 (1988) Environmental testing — Part 1 : General and guidance	IS 9000 (Part 1) : 1988 Basic environmental testing procedures for electronic and electrical items: Part 1 General	Technically equivalent
IEC 68-2-3 (1985) Environmental testing — Part 2 : Tests — Test Ca: Damp heat, steady state	IS 9000 (Part 4) : 1979 Basic environmental testing procedures for electronic and electrical items: Part 4 Damp heat (steady state)	do
IEC 68-2-6 (1995) Environmental testing — Part 2 : Tests — Test Fc and guidance : Vibration (sinusoidal)	IS 9000 (Part 8) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 8 Vibration (sinusoidal) test	do
IEC 68-2-7 (1983) Environmental testing — Part 2 : Tests — Test Ga and guidance : Acceleration, steady state	IS 9000 (Part 9) : 1984 Basic environmental testing procedures for electronic and electrical items: Part 9 Acceleration (steady state) test	do

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Indian Standard
**SEMICONDUCTOR DEVICES — MECHANICAL AND
CLIMATIC TEST METHODS**
(First Revision)

1 Scope and object

This International Standard lists test methods applicable to semiconductor devices (discrete devices and integrated circuits) from which a selection may be made. However, additional test methods may be required for non-cavity devices.

NOTE A non-cavity device is a device in which enclosing or encapsulating material is in intimate contact with all exposed surfaces of the active element, and no void space is included in the device design.

This standard has taken into account, wherever possible, IEC 60068.

The object of this standard is to establish uniform preferred test methods with preferred values for stress levels for judging the environmental properties of semiconductor devices.

In case of contradiction between this standard and a relevant specification, the latter shall govern.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60068-1:1988, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-3:1985, *Environmental testing – Part 2: Tests – Test Ca: Damp heat, steady state*

IEC 60068-2-6:1995, *Environmental testing – Part 2: Tests – Test Fc and guidance: Vibration (sinusoidal)*

IEC 60068-2-7:1983, *Environmental testing – Part 2: Tests – Test Ga and guidance: Acceleration, steady state*

IEC 60068-2-11:1981, *Environmental testing – Part 2: Tests – Test Ka: Salt mist*

IEC 60068-2-13:1983, *Environmental testing – Part 2: Tests – Test M: Low air pressure*

IEC 60068-2-14:1984, *Environmental testing – Part 2: Tests – Test N: Change of temperature*

IEC 60068-2-17:1994, *Environmental testing – Part 2: Tests – Test Q: Sealing*

IEC 60068-2-20:1979, *Environmental testing – Part 2: Tests – Test T: Soldering*

IEC 60068-2-21:1983, *Environmental testing – Part 2: Tests – Test U: Robustness of terminations and integral mounting devices*

IEC 60068-2-45:1980, *Environmental testing – Part 2: Tests – Test XA and guidance: Immersion in cleaning solvents*

IEC 60068-2-47:1982, *Environmental testing – Part 2: Tests – Mounting of components, equipment and other articles for dynamic tests including shock (Ea), bump (Eb), vibration (Fc and Fd) and steady-state acceleration (Ga) and guidance*

IEC 60068-2-48:1982, *Environmental testing – Part 2: Tests – Guidance on the application of the tests of IEC Publication 68 to simulate the effects of storage*

IEC 60653:1979, *General considerations on ultrasonic cleaning*

IEC 60695-2-2:1991, *Fire hazard testing – Part 2: Test methods – Section 2: Needle-flame test*

IEC 60747-1:1983, *Semiconductor devices – Discrete devices and integrated circuits – Part 1: General*

IEC 60748-1:1984, *Semiconductor devices. Integrated circuits – Part 1: General*

3 Terms, definitions and letter symbols

Reference is made to IEC 60068, IEC 60747 and IEC 60748.

4 Standard atmospheric conditions

Reference: IEC 60068-1.

Unless otherwise specified, all tests and recoveries shall be carried out under standard atmospheric conditions for testing, as defined in IEC 60068-1, subclause 5.3:

temperature:	15 °C to 35 °C;
relative humidity:	45 % to 75 %, where appropriate;
air pressure:	86 kPa to 106 kPa (860 mbar to 1060 mbar).

All electrical measurements, as well as recoveries followed by measurements, shall, however, be carried out under the atmospheric conditions:

temperature:	(25 ± 5) °C;
relative humidity:	45 % to 75 %, where appropriate;
air pressure:	86 kPa to 106 kPa (860 mbar to 1060 mbar).

Referee tests shall be carried out under the following standard atmospheric conditions:

temperature:	(25 ± 1) °C;
relative humidity:	48 % to 52 %;
air pressure:	86 kPa to 106 kPa (860 mbar to 1060 mbar).

Before the measurements are made, the specimens shall be stored until temperature equilibrium is reached. The ambient temperature during the measurements shall be stated in the test report.

During measurement, the specimens shall not be exposed to draughts, illumination or other influences likely to cause error.

5 External visual examination and verification of dimensions

5.1 External visual examination

5.1.1 Purpose

To verify that the physical appearance of the materials, design, construction, markings and workmanship of the device are in accordance with the applicable detail specification.

5.1.2 Scope

This test is intended for the outgoing inspection from the device manufacturer's facility or as an incoming user inspection. Additional requirements for the optical systems of optoelectronic devices need to be specified where applicable.

5.1.3 Definition

Chip out: a void in the package material caused by an unintentional breakage.

5.1.4 Test apparatus

Apparatus used in this test shall be capable of demonstrating device conformance to the applicable requirements, which may include optical equipment capable of magnification between 3× and 10× and a relatively large and accessible field of view such as an illuminated ring magnifier.

5.1.5 Test method

The device shall be examined under a magnification of between 3× and 10× (unless otherwise specified) with a field of view sufficiently large to contain the entire device in accordance with the requirements of the applicable specification and the criteria listed in 5.1.6. Where adherence of foreign material is in question, devices may be subjected to a clean filtered air (ionized if devices are electrostatic sensitive) stream (suction or expulsion) of 27 m/s maximum, and reinspected.

5.1.6 Defect criteria

Devices shall be considered defective if they exhibit any of the following:

5.1.6.1 Device design, termination identification, markings (content, placement, and legibility), materials, construction, and workmanship not in accordance with the applicable specification.

5.1.6.2 Defects or damage resulting from manufacturing, handling, or testing, including the following:

- a) Broken packages, voids or cracks in the packages. Cracks, scratches, openings, bubbles and other defects on the surface shall not be cause for failure unless they affect the performance of the package or violate other criteria stated herein, such as markings, finish, etc.
- b) Any chip out dimension that exceeds 1,5 mm in any direction on the surface or has a depth which exceeds 0,2 mm, unless otherwise specified, for example for very small packages.
- c) Any chip out that exposes either sealing glass (not exposed prior to the chip out) or any internal material such as lead frame or conductive layer, that is not intended to be exposed by design.

5.1.6.3 Visible evidence of corrosion, contamination or breakage, broken leads, cracked seals (except glass meniscus), defective (peeling, flaking, or blistering) or damaged plating. Discoloration of the finish shall not be cause for failure unless there is evidence of flaking, pitting, or corrosion. In the case of very small packages, more stringent requirements may be called for in the relevant specification.

5.1.6.4 Leads that are not intact, or aligned in their normal location, or free of sharp or unspecified lead bends, or (for ribbon leads) free of twist outside the normal lead plane.

5.1.6.5 Leads that are not free of foreign material such as paint or other adherent deposits.

5.1.7 Information to be given in the relevant specification

The following details shall be specified in the applicable document:

- a) Requirements for marking and the lead or pin identification (see 5.1.6.1).
- b) Detailed visual requirements specified in drawings.
- c) Chip out dimensions if other than those specified in 5.1.6.2 b).

5.2 Verification of dimensions

Dimensions given in the relevant specification shall be verified.

6 Electrical measurements

6.1 For environmental testing, the characteristics to be checked shall be selected from the chapter "Acceptance and reliability" of the relevant part of IEC 60747 or IEC 60748; they are specified for each device category.

6.2 Measurement conditions: see table "Conditions for the endurance tests" in the chapter "Acceptance and reliability" of the relevant part of IEC 60747 or IEC 60748.

6.3 Initial measurements

If upper specification limit and/or lower specification limit criteria are required only, it is left to the discretion of the manufacturer whether initial measurements are made or not. Initial measurements shall be made where individual values for an individual device are a criterion.

6.4 Measurements monitored during environmental testing

To be stated, where appropriate.

6.5 Final measurements

When the test is called for in the relevant specification as part of a sequence (sub-group) of tests, measurements are required only at the end of the sequence. For certain tests, such as solderability or lead fatigue, electrically defective devices may be used.

CHAPTER 2: MECHANICAL TEST METHODS

The choice of the appropriate tests depends on the type of devices and of the encapsulation. The relevant specification shall state which tests are applicable.

1 Robustness of terminations

Reference: IEC 60068-2-21.

1.1 Tensile

This test shall be in accordance with Test Ua₁, with the following specific requirements:

In 2.6, read:

After test, examine under 3× to 10× magnification.

The device shall be rejected if there is breakage (other than seal meniscus), loosening or relative motion between the lead or terminal and the device body.

1.2 Bending

This test shall be in accordance with Test Ub, with the following specific requirements:

In 4.2, Method 2 is recommended only for dual-in-line and similar packages, where the configuration of the body makes it difficult or impracticable to use Method 1.

1.3 Torsion

This test shall be in accordance with Test Uc, with the following specific requirements:

Method

Method A (severity 2) or Method B shall be used.

Failure criteria

When examining using 10× to 20× magnification after removal of the stress, any evidence of breakage, other than in the seal meniscus, loosening, or relative motion between the terminal lead and the device body shall be considered as a device failure.

1.4 Torque

1.4.1 Torque test for studs

This test shall be in accordance with Test Ud, with the following specific requirements:

The device shall be considered as a failure if any of the following occurs:

- the stud breaks or elongates more than one-half the thread pitch;
- there is evidence of thread stripping or deformation of the mounting seat;
- the device fails electrical measurements after test, if applicable.

1.4.2 Torque test for leads – New test (called Ud₂)

1.4.2.1 Object

To determine the ability of a termination to withstand twisting which may be applied during inspection or servicing after installation.

1.4.2.2 Test method

The component shall be held rigidly and a torque or twist shall be applied slowly to the termination being tested until the twist angle reaches $30^\circ \pm 10^\circ$ or the specified torque is achieved, whichever condition occurs first.

The termination is then returned to its original position. A torque of $1,4 \times 10^{-2} \pm 1,4 \times 10^{-3}$ N·m shall be applied to the termination at a distance of $3,0 \pm 0,5$ mm from the body or within 1 mm from the end of the termination, if it is shorter than 3 mm.

The torque shall be applied in each direction.

When the component has terminations which are formed close to the body, the torque may be applied $3,0 \pm 0,5$ mm from the point where the terminations are formed.

1.4.2.3 Final measurements

After test, examine under $3\times$ to $10\times$ magnification. The component shall be rejected if there is any evidence of termination breakage, loosening or relative motion between the termination and the body.

1.4.2.4 Information to be given in the relevant specification

Number and selection of terminations to be tested.

2 Soldering

Reference: IEC 60068-2-20.

2.1 Solderability

This test shall be in accordance with Test Ta, with the following specific requirements:

- Ageing:
Where accelerated ageing is required by the relevant specification, "ageing 1b" is preferred. Ageing 3 may be used. Ageing 1a and 2 shall not be used.
- Dewetting: (as per 4.9 of Test Ta):
This test shall not be considered mandatory except when it is required in the relevant specification.
- When Method 1 is selected:
Terminals are subjected to the solder-bath method. The terminals are immersed in the bath to within 1,5 mm or other distance, as specified in the relevant specification, from the seating plane of the component.

NOTE When the immersion distance is closer than 1,5 mm to the seating plane of the device, then alternative failure criteria may apply and shall be specified.

- When Method 2 is selected:

Terminals are subjected to the soldering-iron method, using the soldering-iron bit size A. The distance of the soldering-iron application from the body of the component shall be as specified in the relevant specification; the time of soldering-iron application shall be $3,5 \pm 0,5$ s.

- When Method 3 is selected:

Terminals are subjected to the solder globule method. The terminals are tested at a point 5 ± 1 mm from the body of the component. The wire shall be wetted with solder within 2,5 s.

Criteria for good wetting

When observed under 10× magnification, the dipped surface shall be covered with a smooth and bright solder coating, with no more than traces (approximately 5 %) of scattered imperfections such as pin-holes or non-wetted areas. These imperfections shall not be concentrated in one area.

2.2 Resistance to soldering heat

This test shall be in accordance with Test Tb, with the following specific requirements:

Method

Method 1A with an immersion time of 10 ± 1 s, or Method 1B shall be used.

2.3 Resistance of plastic encapsulated SMDs to the combined effect of moisture and soldering heat

2.3.1 Object

This subclause provides a test method for assessing the resistance to soldering heat of plastic encapsulated surface mount devices (SMDs). This test is destructive.

2.3.2 General description

Package cracking and electrical failure in plastic encapsulated SMDs can result when soldering heat raises the vapour pressure of moisture which has been absorbed into SMDs during storage. These problems are assessed. In this test method, SMDs are evaluated for heat resistance after being soaked in an environment which simulates moisture being absorbed while under storage in a warehouse or dry pack.

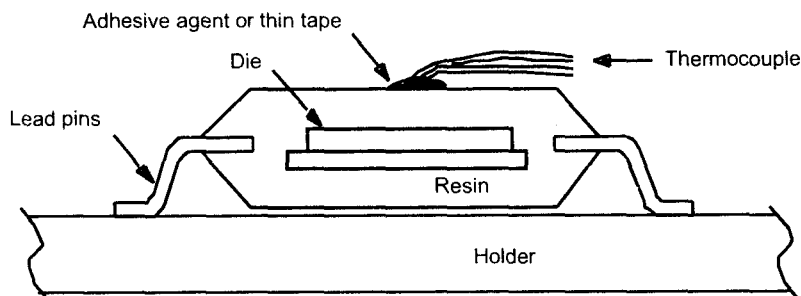
2.3.3 Test apparatus and materials

a) Humidity chamber

The humidity chamber shall provide an environment complying with the temperature and relative humidity defined in item c) of 2.3.4.

b) Reflow soldering apparatus

The infra-red convection, the convection and the vapour-phase reflow soldering apparatus shall provide temperature profiles complying with the conditions of soldering heat defined in items d)1) and d)2) of 2.3.4. The settings of the reflow soldering apparatus shall be adjusted by temperature profiling of the top surface of the specimen while it is undergoing the soldering heat process, measured as shown in figure 1.



NOTE The adhesive agent or thin tape should have good thermal conductivity.

Figure 1 – Method of measuring the temperature profile of a specimen

c) Holder

Unless otherwise detailed in the relevant specification, any board material, such as epoxy fibreglass or polyimide, may be used for the holder. The specimen shall be placed on the holder by the usual means and in a position as shown in figure 1. If the position of the specimen, as shown in figure 1, necessitates changing the shape of terminations and results in subsequent electrical measurement anomalies, a position that avoids changing the shape of terminations may be chosen, and this shall be specified in the relevant specification.

d) Wave-soldering apparatus

The wave-soldering apparatus shall comply with conditions given in item d)3) of 2.3.4. Molten solder shall usually be flowed.

e) Solvent for vapour-phase reflow soldering

Perfluorocarbon (perfluoroisobutylene) shall be used.

f) Flux

Unless otherwise detailed in the relevant specification, the flux shall consist of 25 % by weight of colophony in 75 % by weight of isopropyl alcohol, both as specified in appendix C of IEC 60068-2-20.

g) Solder

Solder of composition as specified in appendix B of IEC 60068-2-20 shall be used.

2.3.4 Procedure

a) Initial measurements

1) Visual inspection

Visual inspection, as specified in clause 5 of chapter 1, shall be performed before the test. Special attention shall be paid to external cracks and swelling, which will be looked for under a magnification of 40×.

2) Electrical measurement

Electrical testing shall be performed as required by the relevant specification.

3) Internal inspection by acoustic tomography

Unless otherwise detailed in the relevant specification, internal cracks and delamination in the specimen shall be inspected by acoustic tomography in accordance with appendix I.

b) Drying

Unless otherwise detailed in the relevant specification, the specimen shall be baked at $125\text{ °C} \pm 5\text{ °C}$ for at least 24 h.

c) Moisture soak

Unless otherwise detailed in the relevant specification, moisture soak conditions shall be selected on the basis of the packing method of the specimen (see II.1.1 of appendix II). If baking the specimen before soldering is detailed in the relevant specification, the specimen shall be baked instead of being subject to moisture soak.

1) Moisture soak for dry-packed SMDs

Moisture soak conditions for dry-packed SMDs may be used as specified in method A, table 1, or method B, table 2. Moisture soak conditioning for dry-packed SMDs consists of two stages. The first stage of conditioning is intended to simulate moisturizing SMDs before opening the dry pack/dry cabinet. The second stage of conditioning is to simulate moisturizing SMDs during storage after opening the dry pack for soldering (floor life). Moisture soak conditioning for dry-packed SMDs shall be selected from method A or B. Method A shall be used when the relative humidity in the dry pack or dry cabinet is specified by the manufacturer as being between 10 % and 30 %. Method B shall be used when the relative humidity in the dry pack or dry cabinet is specified by the manufacturer as being below 10 %.

i) Method A

Unless otherwise detailed in the relevant specification, the first stage of conditioning A1, as shown in table 1, shall be performed. Subsequently, the second stage of conditioning A2, as shown in table 1, shall be performed within 4 h of finishing the first stage of conditioning (see II.1.2.2 of appendix II).

Table 1 – Moisture soak conditions for dry-packed SMDs (method A)

Condition		Moisture soak conditions	Permissible storage conditions in the dry pack and the dry cabinet	Condition of floor life
First-stage conditioning	A1	$(85 \pm 2) ^\circ\text{C}$, $(30 \pm 5) \% \text{ RH}$, $168 \begin{smallmatrix} 24 \\ -0 \end{smallmatrix} \text{ h}$	$<30 ^\circ\text{C}$, 30 % RH, 1 year	–
Second-stage conditioning	A2	$(30 \pm 2) ^\circ\text{C}$, $(70 \pm 5) \% \text{ RH}$, $168 \begin{smallmatrix} 24 \\ -0 \end{smallmatrix} \text{ h}$	–	$<30 ^\circ\text{C}$, 70 % RH, 168 h
RH: Relative humidity.				

NOTE 1 The first stage of conditioning represents storage conditions in the dry pack and the dry cabinet, as well as increasing relative humidity in the dry pack, by repacking the SMDs at the distributor's facility and the user's inspection facility. When condition A1 is applied, the SMDs must be packed into a moisture-proof bag with IC trays and desiccants within a few weeks of drying. They may then be subjected to multiple temporary openings of the moisture-proof bag (for several hours at a time). Repack and inspection of SMDs are possible while the humidity indicator in the dry pack indicates less than 30 % RH since SMDs will recover the initial condition of absorbed moisture within a few days of repacking. In this case, the moisture content measurement of SMDs (see clause II.2 of appendix II) is not needed as a moisture control of the dry pack. A check of the moisture indicator is sufficient for moisture control.

NOTE 2 When moisture soak of the first-stage conditioning does not result in saturation, the soak time is extended to 336 h, because SMDs in a dry pack or dry cabinet will become saturated with moisture during long-term storage. When moisture soak of the first stage of conditioning reaches saturation, the soak time is shortened.

ii) Method B

The condition of moisture soak conditioning shall be selected from table 2 in accordance with the condition of the floor life detailed in the relevant specification (see II.1.2.3 of appendix II).

Table 2 – Moisture soak conditions for dry-packed SMDs (method B)

Condition	Moisture soak conditions	Total conditions from baking to dry packing and temporary opening of the dry pack	Condition of floor life
B1	(30 ± 2) °C, (60 ± 5) % RH, 192 ⁺²⁴ ₋₀ h	<30 °C, 60 % RH, 24 h	<30 °C, 60 % RH, 168 h
B2	(30 ± 2) °C, (60 ± 5) % RH, 96 ⁺²⁴ ₋₀ h	<30 °C, 60 % RH, 24 h	<30 °C, 60 % RH, 72 h
B3	(30 ± 2) °C, (60 ± 5) % RH, 72 ⁺²⁴ ₋₀ h	<30 °C, 60 % RH, 24 h	<30 °C, 60 % RH, 48 h
B4	(30 ± 2) °C, (60 ± 5) % RH, 48 ⁺²⁴ ₋₀ h	<30 °C, 60 % RH, 24 h	<30 °C, 60 % RH, 24 h
B5	(30 ± 2) °C, (60 ± 5) % RH, 6 ⁺²⁴ ₋₀ h	–	<30 °C, 60 % RH, 6 h

RH: Relative humidity.

NOTE 3 Moisture soak conditions from B1 to B4 consist of the first-stage conditioning (30 °C, 60 % RH, 24 h) and the second-stage conditioning (floor life).

NOTE 4 Contents in the dry pack of SMDs, IC trays and other materials, should be fully dried just before packing into the moisture-proof bag and the desiccant must be completely dry. This is because moist materials and degraded desiccants give off water vapour, causing the relative humidity in the dry pack to exceed 10 %. The relative humidity in the dry pack should be verified by the humidity indicator and the moisture content measurement of the SMDs, as shown in clause II.2 of appendix II.

NOTE 5 Storage of SMDs in a dry cabinet instead of a dry pack is not permitted because very low relative humidity cannot be obtained in a dry cabinet.

NOTE 6 The individual conditions of method B shall cover total storage condition from baking the SMDs to soldering them, and this should include the duration time of room storage from baking the SMDs to packing them into the dry pack, temporary opening of the dry pack and the floor life.

2) Conditions for non-dry-packed SMDs

The moisture soak condition shall be selected from table 3, in accordance with the permissible limit of actual storage (see II.1.2.1 of appendix II).

Table 3 – Moisture soak conditions for non-dry-packed SMDs

Condition	Temperature °C	Relative humidity %	Duration time h	Permissible limit on actual storage
C	85 ± 2	85 ± 5	168 ± 24	<30 °C, 85 % RH
D	85 ± 2	60 ± 5	168 ± 24	<30 °C, 60 % RH

RH: Relative humidity.

d) Soldering heat

Unless otherwise detailed in the relevant specification, the specimen shall be subjected to soldering heat within 4 h of finishing the moisture soak or baking. The method and condition of soldering heat shall be selected from items d)1) to d)3) of this subclause according to the relevant specification. Whichever method is chosen, the soldering heat cycles shall be a minimum of one and a maximum of three. Unless otherwise detailed in the relevant specification, one cycle of soldering heat shall be used. If more than one cycle is selected, the specimen shall be cooled down to below 50 °C before the second, and subsequent, soldering heat.

NOTE 7 If the specimen is not affected by moisture soak and drying, which takes place during room storage of over 4 h, a storage time exceeding 4 h following the completion of moisture soak or the baking may be detailed in the relevant specification.

1) Method of heating by infra-red convection or convection reflow soldering

i) Preparation

The specimen shall be put on the holder.

ii) Preheating

Unless otherwise specified in the relevant specification, the specimen shall be preheated at a temperature from 100 °C to 160 °C for 1 min to 2 min in the reflow soldering apparatus.

iii) Solder heating

Following preheating, the temperature of the specimen shall be raised to peak temperature and then lowered to room temperature. The heating condition shall be selected from table 4 in accordance with the relevant specification.

NOTE 8 If the SMDs are thick and large, condition I-B should be selected, since the temperature of thick and large SMDs having a large heat capacitance will not reach 220 °C during actual reflow soldering (see II.3.1 of appendix II).

NOTE 9 Following preheating, the temperature of the specimen should follow the values as indicated in the profile given in figure II.9 or figure II.10 of appendix II.

**Table 4 – Heating condition for infra-red convection reflow
and convection reflow soldering**

Condition	Time s	Range of peak temperature °C
I-A	10 ± 1	235 to 240
I-B	10 ± 1	220 to 225

2) Method of heating by vapour-phase reflow soldering

i) Preparation

The specimen shall be put on the holder.

ii) Preheating

Unless otherwise specified in the relevant specification, the specimen shall be preheated at a temperature from 100 °C to 160 °C for 1 min to 2 min in the vapour-phase soldering apparatus.

iii) Solder heating

The temperature of the specimen shall be raised after preheating. When the temperature of the specimen has reached 215 °C ± 5 °C, it shall be maintained for 40 s ± 4 s as shown in table 5 (refer to II.3.2 of appendix II).

Table 5 – Heating condition for vapour-phase soldering

Condition	Temperature °C	Time s
II-A	215 ± 5	40 ± 4

3) Method of heating by wave-soldering

i) Preparation

The bottom surface of the specimen shall be fixed to the holder by an adhesive agent specified in the relevant specification. Unless otherwise detailed in the relevant specification, flux shall not be applied to the specimen and holder.

NOTE 10 If flux is applied, vaporization of solvent in the flux could affect the temperature rise of the specimen. Flux should not, therefore, be applied to the body of the specimen and should only be applied to lead pins as sparingly as possible.

NOTE 11 Where SMDs have a stand-off (height between the bottom of the SMD body and the bottom of the lead pin) of less than 0,5 mm (except lower thermal resistance SMDs with a heat sink and whose body thickness exceeds 2,0 mm), they should be tested by soldering heat of condition I-A. SMDs whose body thickness exceeds 3,0 mm are tested by soldering heat by condition I-B. Wave-soldering of conditions III-A and III-B should be omitted because conditions I-A and I-B are more severe than conditions III-A and III-B for these SMDs (refer to II.3.3 of appendix II).

ii) Preheating

Unless otherwise detailed in the relevant specification, the specimen shall be preheated at a temperature of 80 °C to 140 °C for 30 s to 60 s in the soldering apparatus.

iii) Solder heating

Following preheating, the specimen and the holder shall be immersed into flowing molten solder, as shown in figure 2. The immersion condition shall be selected from table 6.

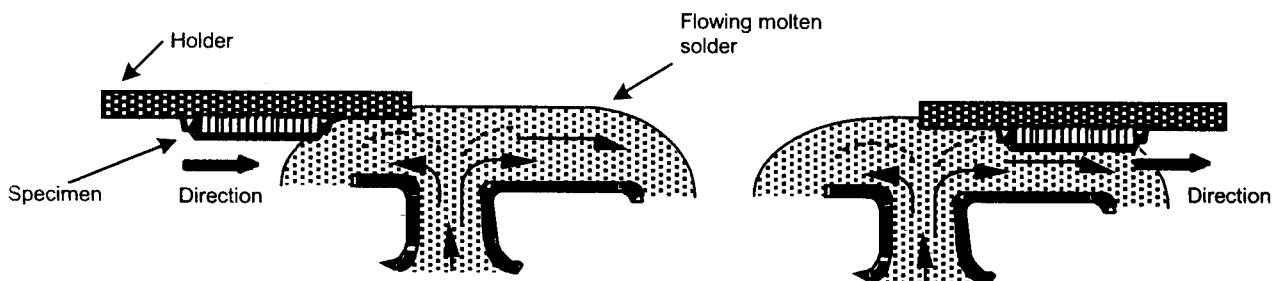


Figure 2a – Start of immersion

Figure 2b – End of immersion

Figure 2 – Heating by wave-soldering

Table 6 – Immersion conditions for wave-soldering

Condition	Temperature of solder °C	Immersing time s	Actual soldering method
III-A	260 ± 5	5 ± 1	Single-wave
III-B	260 ± 5	10 ± 1	Double-wave

iv) Cleaning

If the flux is applied, it shall be removed by a cleaning method detailed in the relevant specification.

e) Recovery

If recovery is detailed in the relevant specification, the specimen shall be stored under standard atmospheric conditions for the time given in the specification.

NOTE 12 Wave-soldering is not commonly available to the semiconductor manufacturer. Where the manufacturer does not have access to such equipment, the method should be specified only by agreement between the manufacturer and the customer.

f) Final measurements

- 1) Visual inspection, as specified in clause 5 of chapter 1, shall be performed after the test. Special attention shall be paid to external cracks and swelling which will be looked for under a magnification of 40×.

- 2) Electrical measurement

Electrical testing shall be performed as required by the relevant specification.

- 3) Internal inspection by acoustic tomography

Unless otherwise specified in the relevant specification, internal cracks and delamination in the specimen shall be inspected by acoustic tomography in accordance with appendix I.

2.3.5 Information to be given in the relevant specification

	Subclause
	2.3.3
a) Material of holder	item c)
b) Position of specimen on the holder	item c)
c) Composition of flux	item f)
d) Number of test specimens	2.3.4
e) Item and failure criteria for initial measurement	item a)
f) Preconditioning	item b)
g) Method of moisture soak	item c)
h) Conditions of drying	item b)
i) Baking conditions instead of the moisture soak	item c)
j) Method of moisture soak for dry packed SMDs	item c)1)
k) Period between the stages of moisture soak conditioning	item c)1)i)
l) Conditions of first-stage and second-stage conditioning and whether another condition is needed	item c)1)i)
m) Soak time of the first-stage conditioning if 168 h of soak time is insufficient	item c)1)i)
n) Moisture soak conditions for SMDs stored in completely dried dry pack	item c)1)ii)
o) Moisture soak conditions for non-dry-packed SMDs	item c)2)
p) Period between finish of moisture soak and soldering heat	item d)
q) Method and condition of soldering heat	item d)
r) Number of cycles of soldering heat	item d)
s) Preheat conditions for infra-red convection and convection reflow soldering	item d)1)
t) Heating conditions for infra-red convection and convection reflow soldering	item d)1)
u) Preheat conditions for vapour-phase reflow soldering	item d)2)
v) Adhesion method	item d)3)
w) Preheat conditions for wave-soldering	item d)3)
x) Cleaning method for flux	item d)3)
y) Recovery conditions	item e)
z) Item and failure criteria for final measurement	item f)

Appendix I (normative)

Methods of inspection by acoustic tomography

I.1 Object

Inspection by acoustic tomography is required by 2.3.4 in order to inspect the specimen's initial internal integrity and internal integrity anomalies subsequent to solder heating.

I.2 Equipment

An acoustic tomography unit capable of operating in the C-Scan (plane image) mode within the 10 MHz to 75 MHz frequency range with an accuracy of 0,5 mm² or more in the area of plane image.

I.3 Procedure of inspection

I.3.1 Select the highest usable ultrasonic frequency, subject to the limitations imposed by the media thicknesses and acoustic characteristics, specimen configuration and transducer availability, to address the interfaces to be inspected (attenuation of the signal with depth).

I.3.2 Complete transducer calibration and optimization in accordance with the manufacturer's recommended procedure.

I.3.3 Bake all specimens suspected or known to have absorbed water through external cracks for the period and temperature required to remove all moisture.

I.3.4 Place the specimens in the acoustic tomography apparatus. Unless otherwise detailed in the relevant specification, the sides, top and bottom of the specimen shall be inspected.

I.3.5 Unless otherwise detailed in the relevant specification, the focus of the ultrasonic beam shall be adjusted to the first interfaces (for example the surface of the die for the top-side inspection and the bottom surface of the die pad for the bottom-side inspection). If any integrity anomalies remote from the first interfaces are detected, the focus shall be changed accordingly.

I.3.6 Optimize the signal-to-noise response of the acoustic system and units under evaluation.

I.3.7 Complete inspection for all specimens specified in 2.3.4.

1.4 Failure criteria

1.4.1 Unless otherwise detailed in the relevant specification, the following internal integrity anomalies shall be unacceptable.

- a) Delamination of any area on the top surface of the die.
- b) Internal resin cracking that intersects a bond wire, ball bond, or wedge bond.
- c) Internal resin cracking extended to any internal feature (for example, from die pad to lead finger).
- d) Internal resin cracking extending more than two-thirds of the distance from any internal feature to the outside of the specimen. These additional internal integrity anomalies shall be unacceptable if the area and location of the delamination or crack are specified in the relevant specification.
- e) Wide delamination of any internal feature that intersects a bond wire, ball bond, or wedge bond.
- f) Wide delamination or wide internal crack that degrades an electrical or thermal specification.

NOTE 1 If internal resin cracks of b), c), d) and f) above are suspected (based on acoustic tomography), polished cross-sections must be made to verify the suspected sites.

NOTE 2 Internal integrity anomalies in this subclause are specified in order to avoid failures such as external cracks, electrical and thermal failures in the population of the specimens. Other integrity anomalies that may generate reliability failures must be checked by other reliability tests as stated in 1.4.2.

1.4.2 Unless otherwise detailed in the relevant specification, internal integrity anomalies other than a), b), c), d), e) and f) detailed in 1.4.1 may be listed as grounds for rejection.

NOTE Some internal integrity anomalies in this subclause may need to be assessed by alternative reliability tests such as the climatic test of chapter 3.

1.5 Information to be given in the relevant specification

	Subclause
a) Side to be inspected if different from specification	1.3.4
b) Focus of ultrasonic beam if different from specification	1.3.5
c) Area and location of delamination	item e) of 1.4.1
d) Area and location of delamination or crack	item f) of 1.4.1
e) Additional internal integrity anomalies to be judged as unacceptable	1.4.2

Appendix II (informative)

Details and descriptions of test method on resistance of plastic encapsulated SMDs to the combined effect of moisture and soldering heat

II.1 Description of moisture soak

II.1.1 Guidance for moisture soak

Method A and method B of moisture soak of item c) of 2.3.4 are intended to be used for dry-packed SMDs, whereas conditions C and D in table 3 are intended for use with non-dry-packed SMDs which have been stored under room conditions.

Where package cracking is generated by soldering heat after the moisture soak of condition C or D, it is recommended that devices be dry-packed or stored in a dry atmosphere.

If the cracking is generated by solder heating after the moisture soak of method A and method B, it is recommended that SMDs are pre-baked before being soldered on to the PCBs.

II.1.2 Considerations on which the condition of moisture soak is based

II.1.2.1 General description of moisture soak

The presence of moisture in SMDs is caused by diffusion of water vapour into the resin. The moisture content of the resin needs to be examined, since package cracking during soldering emanates from near the die pad or the die. Examples of characteristics for moisture soak at 85 °C, 85 % relative humidity, are shown in figure II.1. In the case where the resin thickness from the bottom surface of the package to the die pad is 1 mm, figure II.1 indicates that over 168 h are needed for saturation to take place.

Moisture soak characteristics, such as that of resin A in figure II.3, show a slow moisture soak speed which is nevertheless considered significant. Figure II.1 and figures II.4 to II.8 represent moisture soak characteristics of resin A.

Saturation is needed for soldering heat tests in order to simulate long-time storage of, for example, one year which occurs when SMDs are dry-packed or warehoused. The diffusion speed of water vapour into resin depends only on temperature. Given the resin thickness as defined in figure II.2, saturating moisture time at 85 °C depends on the resin thickness as shown in figure II.3. It would appear that, for a normal SMD whose resin thickness is from 0,5 mm to 1,0 mm, 168 h of moisture soak time are required.

The saturated moisture content of resin depends on temperature and relative humidity as shown in figure II.4. The relative humidity required for moisture soak can be determined from figure II.4 (for example, so that the content of moisture at 85 °C can be made to correspond with the content of moisture at 30 °C, the actual storage temperature). Conditions of moisture soak for soldering heat tests are derived from figure II.4 as shown in table II.1.

Figure II.5 shows the moisture content in resin at the first interface (top surface of die or bottom surface of die pad) under conditions of moisture soak and real storage conditions.

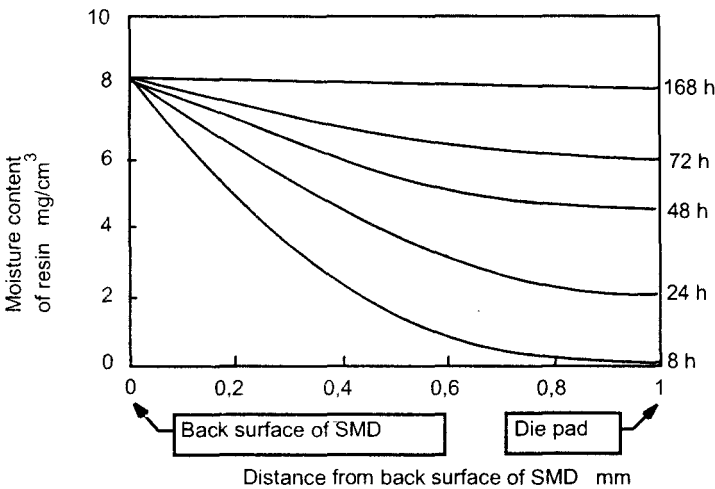
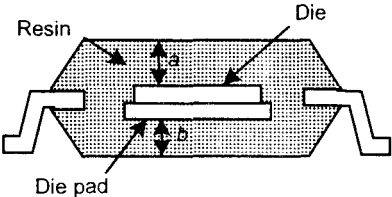


Figure II.1 – Process of moisture diffusion at 85 °C, 85 % RH



NOTE "a" or "b": the thicker of the two is defined as the resin thickness and the top surface of the die or the bottom surface of the die pad is defined as the first interface.

Figure II.2 – Definition of resin thickness and the first interface

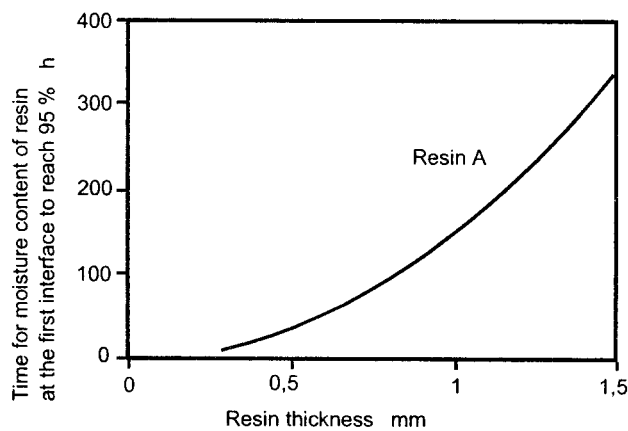


Figure II.3 – Moisture soak time to saturation at 85 °C as a function of resin thickness

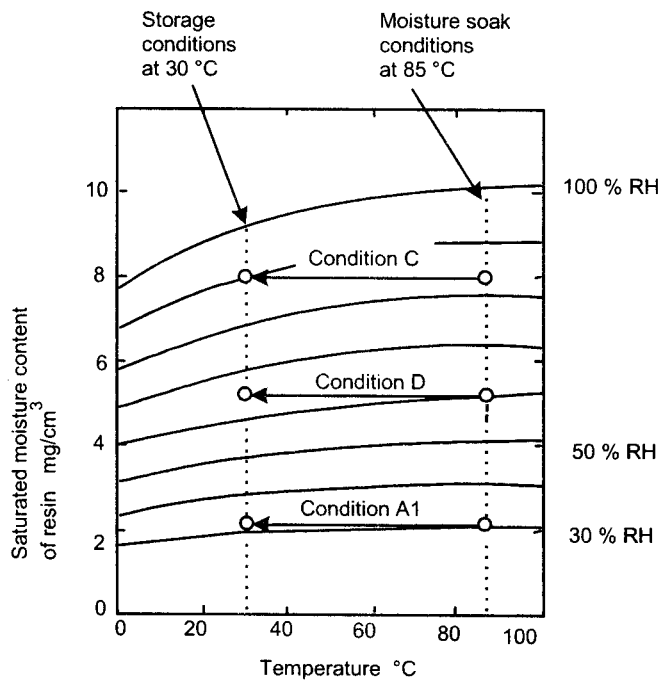


Figure II.4 – Temperature dependence of saturated moisture content of resin

Table II.1 – Comparison of actual storage conditions and equivalent moisture soak conditions before soldering heat

Condition	Actual conditions of storage	Relative humidity for moisture soak at 85 °C %
A1	30 °C max., 30 % RH max.	30 ± 5
C	30 °C max., 85 % RH max.	85 ± 5
D	30 °C max., 60 % RH max.	60 ± 5

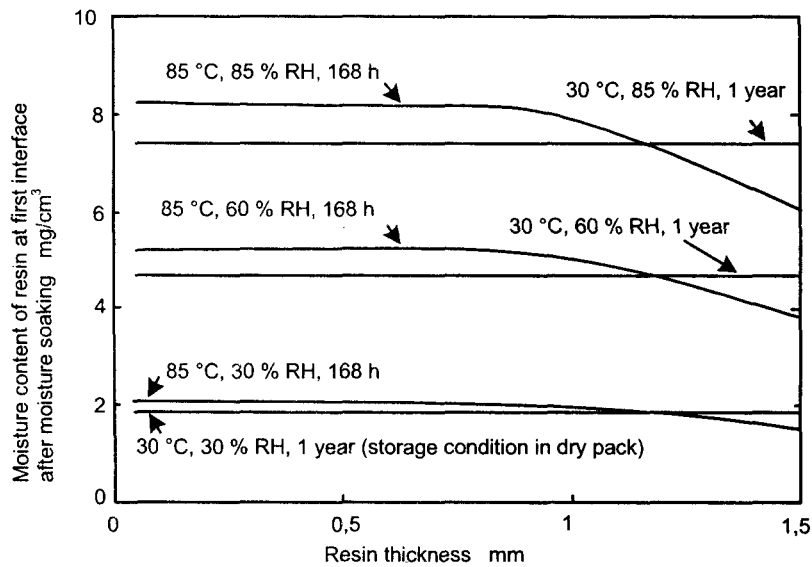


Figure II.5 – Dependence of moisture content of resin at the first interface on resin thickness under various soak conditions

II.1.2.2 Moisture soak conditioning – Method A

Method A of moisture soak given in item c)1)i) of 2.3.4 is based on conditions where SMDs are stored in a dry pack or dry cabinet for a long time, under permissible conditions of 30 °C, 30 % RH, for one year, and where the packing/cabinet can be opened temporarily any number of times for a few hours at a time, provided the humidity indicator indicates below 30 % RH.

Figure II.6 shows that the first-stage conditioning A1 and the second-stage conditioning A2 completely represents a floor life of 30 °C, 70 % RH, 168 h after opening the dry pack even though the dry pack is degraded into a condition of 30 % RH.

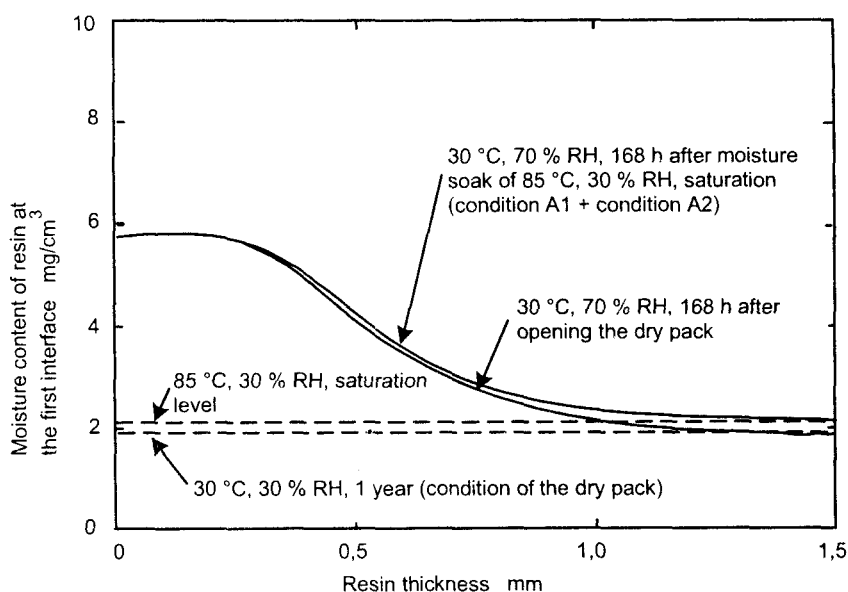


Figure II.6 – Dependence of moisture content of resin at the first interface on resin thickness related to method A of moisture soak

II.1.2.3 Moisture soak conditioning – Method B

Method B of moisture soak given in item c)1)ii) of 2.3.4 is based on conditions where SMDs, IC trays and other materials have been completely baked immediately before dry packing and the volume of dried desiccant added to the enclosure bag ensures absorption of moisture diffused through the enclosure bag. Integrity of the dry pack is verified through

- use of *in situ* moisture control indicators of a sensitivity that will alert for loss of enclosure bag integrity; and
- determination of SMD moisture content as shown in clause II.2. Environmental exposure time includes the time from SMD bake to dry pack, the time the dry pack may be temporarily opened at the distributor's facility, and the package floor life.

Figure II.7 shows the calculated relation between method B conditions and long-term storage at elevated moisture conditions. This calculated figure indicates that conditions B1 to B5 demonstrate potential correlation problems for thick SMDs where the moisture content of the storage environment is greater than 10 %.

In SMDs with interface to package exterior thickness greater than 1 mm, conditions B1 to B5 are no more severe than 30 °C, 10 % RH, for one-year storage. Therefore, if a 10 % RH saturation condition at the interface is deemed to have a significant effect on the reflow performance, thick SMDs assessed with method B conditions shall be stored in conditions lower than 10 % RH.

Figure II.8 provides an example of how the calculated interface moisture content of condition B-tested products may not adequately replicate the calculated interface moisture content for the most used environments at greater than 10 % moisture content.

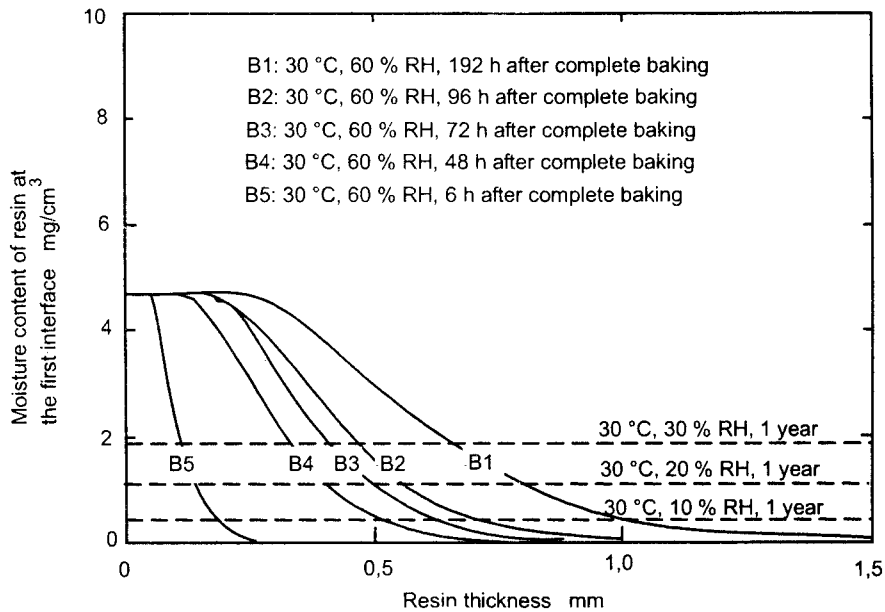


Figure II.7 – Dependence of the moisture content of resin at the first interface on resin thickness related to method B of moisture soak

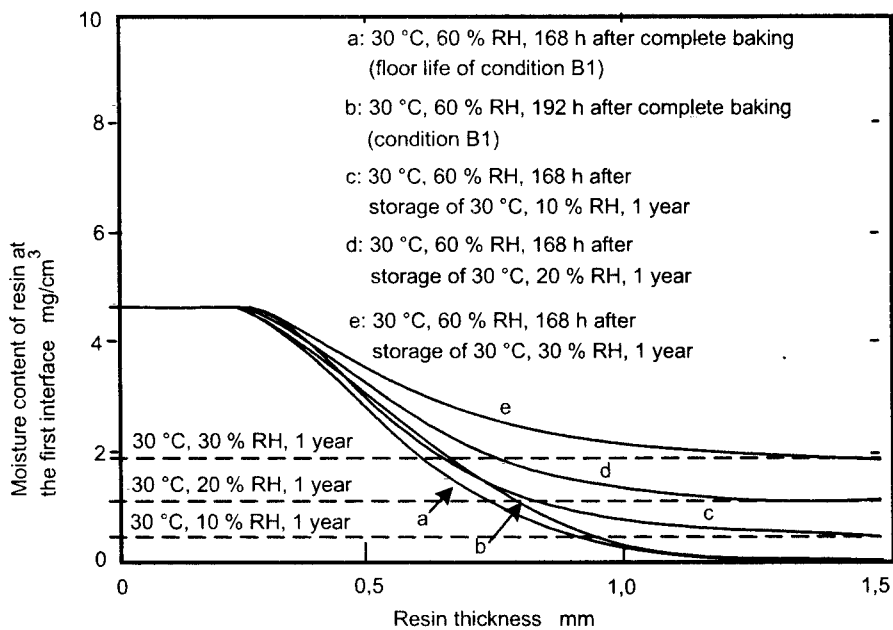


Figure II.8 – Dependence of moisture content of resin at the first interface on resin thickness related to condition B1 of method B of moisture soak

II.2 Procedure for moisture content measurement

The moisture content of a device (MCD) is often used to provide an indication of moisture content in SMDs. Measurement of the MCD shall, however, be used carefully for the following reasons:

- when the moisture soak does not result in saturation, the moisture content of the resin at the first interface will not be representative, since moisture distribution in SMDs may be variable. For example, the surface of the SMD may contain a high level of moisture whereas the inner part of the device is dry, and vice versa;
- though the moisture content of resin is equal, according to the ratio of resin in the device, the MCD varies.

A procedure for measuring the moisture content of a device is described as follows:

- the device is weighed with an accuracy of 0,1 mg per device (x);
- as permitted by the absolute maximum rating of storage temperature in the relevant specification, the device is dried for 24 h at 150 °C or 48 h at 125 °C;
- the device is allowed to cool down to room temperature for 30 min ± 10 min;
- the device is re-weighed (y);
- the moisture content of the device (MCD) is calculated using the following equation:

$$\text{MCD} = 100 \left(\frac{x-y}{y} \right) \%$$

II.3 Soldering heat methods

II.3.1 Temperature profile of infrared convection and convection reflow soldering

Solder heating using infrared convection or convection reflow soldering specified in d)1) of 2.3.4 shall be performed according to the temperature profile shown in figure II.9.

If the temperature of the top surface of the SMD is below 220 °C for real-life reflow soldering, the lower temperature profile shown in figure II.10 can be applied.

In order to get a good solder joint between SMDs and the PCB, the temperature of the solder joint is usually required to be at least 215 °C. Since the temperatures at several points of the PCB are not stable during infrared convection reflow soldering, a maximum temperature of 235 °C will be reached at certain solder joints in order to maintain the temperature of all solder joints of all SMDs on the PCB over 215 °C.

For typical SMDs, the temperature of the top surface will reach in excess of 220 °C when the temperature of the solder joints is set at 235 °C. Accordingly, the profile of figure II.9 shall be selected.

Thick and large SMDs (over 3,0 mm in thickness and over 2 000 mm³ in volume for example) with a large heat capacitance have a tendency for the temperature of the top surface not to reach 220 °C under many heating conditions. Figure II.10 should, therefore, be selected and the temperature profile to be applied shall be detailed in the relevant specifications.

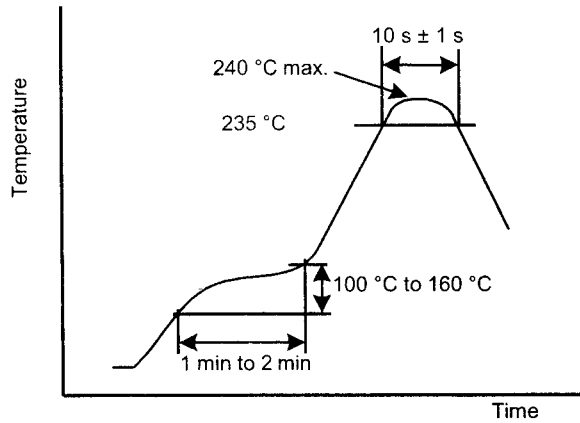


Figure II.9 – Temperature profile of infrared convection and convection reflow soldering (condition I-A)

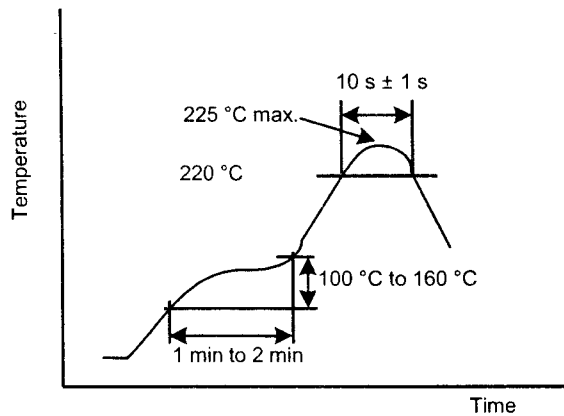


Figure II.10 – Temperature profile of infrared convection and convection reflow soldering (condition I-B)

II.3.2 Temperature profile of vapour-phase soldering

Solder heating using the vapour-phase soldering specified in d)2) of 2.3.4 shall be performed according to the temperature profile shown in figure II.11.

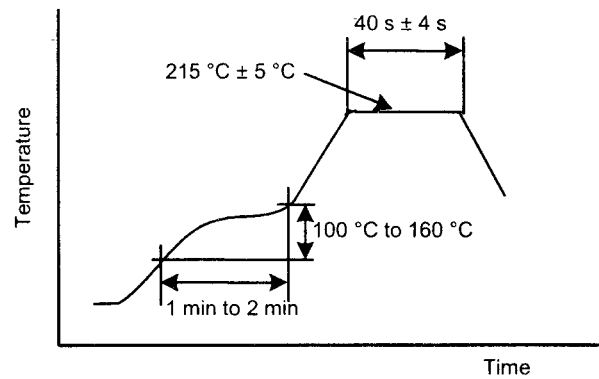


Figure II.11 – Temperature profile of vapour-phase soldering (condition II-A)

II.3.3 Heating method by wave-soldering

The method of immersion into a solder bath as shown in figure II.12 does not correspond exactly with real wave soldering criteria because the molten solder does not enter the gap between the PCB and the SMD's body during real wave-soldering. Consequently, the temperature of the SMD during real wave-soldering is lower than that during the immersion method into a solder bath. When the immersion method is performed for ICs and LSIs having a large heat capacity, the device's body temperature becomes higher than that resulting from the wave-soldering method, by between 10 °C and 80 °C. When SMDs are large, such as QFP and QFJ, the differential could be between 50 °C and 80 °C. Consequently, the wave-soldering method as shown in figure 2 of item d)3) of 2.3.4 shall be performed for the soldering heat test. Package cracking is generated by rapid temperature rise at the first interface during solder heating.

Figure II.13 shows the relationship between the thickness of the SMD's body and the peak temperature at the first interface under each type of solder heating. In SMDs having a stand-off (the height between the bottom of the SMD's body and the bottom of the lead pin) of less than 0,5 mm (excluding lower thermal resistance SMDs having a heat sink), if the body thickness of the SMD exceeds 2,0 mm and solder heating by condition I-A is used, the wave-soldering method can be omitted. Similarly, when the thickness exceeds 3,0 mm and solder heating by condition I-B is used, the wave-soldering method can also be omitted. For SMDs having a stand-off exceeding 0,5 mm (see figure II.14) or having a heat sink, wave-soldering cannot be omitted because their body temperature will be higher than that shown in figure II.13.

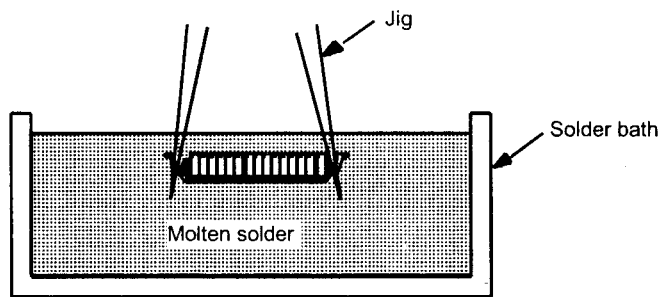


Figure II.12 – Immersion method into solder bath

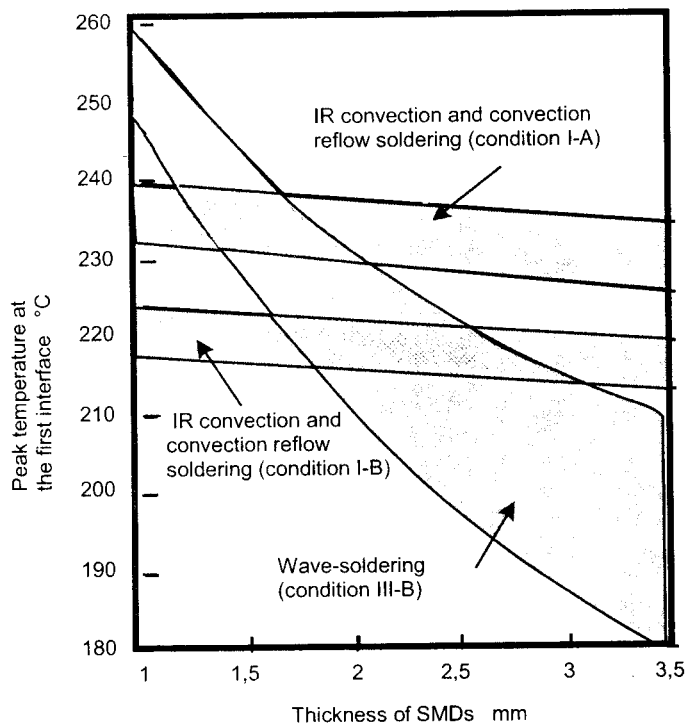


Figure II.13 – Relation between the infrared convection reflow soldering and wave-soldering

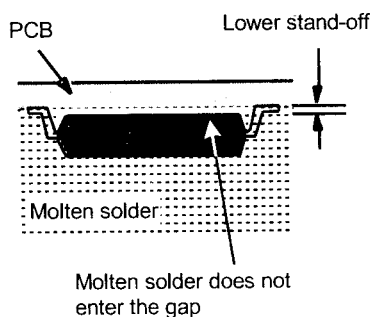


Figure II.14a – Lower

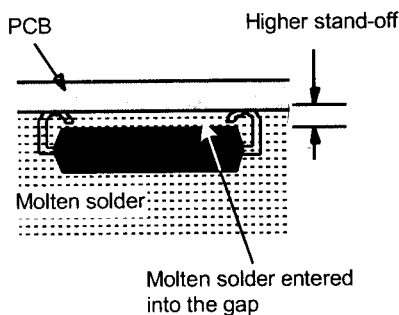


Figure II.14b – Higher

NOTE The reason for the differential of the SMD temperature depends on the height of the stand-off.

Figure II.14 – Temperature in the body of the SMD during wave-soldering

3 Vibration (sinusoidal)

Reference: IEC 60068-2-6.

This test shall be in accordance with test Fc, with the following specific requirements:

- the body and leads of the device shall be securely clamped during the test;
- endurance by sweeping;
- acceleration: 196 m/s² (20 g_n);
- frequency range: 100 Hz to 2 000 Hz;
- number of cycles per axis: 15.

4 Shock

Reference: IEC 60068-2-27.

This test shall be in accordance with Test Ea, with the following specific requirements:

The conditions shall be selected from table 7, taking into consideration the mass of the device and its internal construction.

Table 7

Peak amplitude	Duration	Waveform
14 700 m/s ² (1 500 g _n)	0,5 ms	Half-sine
4 900 m/s ² (500 g _n)	1,0 ms	Half-sine
980 m/s ² (100 g _n)	6,0 ms	Half-sine

The device shall be subjected to three successive shocks, in both directions of three mutually-perpendicular axes so chosen that faults are most likely to be revealed, i.e. a total of 18 shocks (see IEC 60068-2-27, subclause 5.2).

The body and leads of the device shall be securely fastened during the test.

5 Acceleration, steady state

Reference: IEC 60068-2-7.

This test shall be in accordance with Test Ga, with the following specific requirements:

Mounting

According to clause 4 of IEC 60068-2-47 the case being clamped and the leads restrained.

Procedure

Unless otherwise specified, the acceleration shall be applied for at least 1 min along one axis so chosen that the force is exerted in a pull direction with respect to the die.

Severities

500 000 m/s ² (50 000 g _n)	
300 000 m/s ² (30 000 g _n)	Preferred severity
200 000 m/s ² (20 000 g _n)	
100 000 m/s ² (10 000 g _n)	
50 000 m/s ² (5 000 g _n)	

Information to be given in the relevant specification

- a) severity;
- b) axes and directions of acceleration.

6 Bond strength test

6.1 General

6.1.1 Object

To measure bond strength or determine compliance with specified bond strength requirements.

6.1.2 General description of the test

Seven test methods are described, each having its own purpose, that is:

- methods A and B are intended for testing internal bonds of a device by a direct pulling of the connecting wire;
- method C is intended for bonds external to the device and consists of a peeling stress exerted between the lead or terminal and the board or substrate;
- method D is intended for internal bonds and consists of a shear stress applied between a die and a substrate or similar face-bonded configurations;
- methods E and F are intended for external bonds and consist of a push-off or a pull-off stress exerted between a die and the substrate;
- method G is intended to test the mechanical resistance of wire bonds to a shear force.

6.1.3 Description of the test apparatus (for all methods)

The apparatus for this test should consist of a suitable equipment for applying the specified stress on the bond, lead wire or terminals as required in the specified test method. A calibrated measurement and indication of the applied stress in Newtons (N) at the point of failure should be provided by equipment capable of measuring stresses up to and including 100 mN with an accuracy of $\pm 2,5$ mN, stresses between 100 mN and 500 mN with an accuracy of ± 5 mN, and stresses exceeding 500 mN with an accuracy of $\pm 2,5$ % of the indicated value.

6.2 Methods A and B (see also annex A)

6.2.1 Scope

This test is intended to be applied to the wire-to-die bond, wire-to-substrate bond, or the wire-to-terminal bond inside the package of wire-connected semiconductor devices bonded by soldering, thermocompression, ultrasonic and other related techniques.

6.2.2 General description of the test

6.2.2.1 Method A: Wire pull (applied to bonds separately)

The wire connecting the die or substrate should be cut so as to provide two ends accessible for a pull test. In the case of short wire runs, it may be necessary to cut the wire close to one termination in order to allow the pull test at the opposite termination. The wire should be gripped in a suitable device and simple pulling action applied to the wire or to the device (with the wire clamped) in such a manner that the force is applied within 5° of the parallel to the surface of the die or substrate in the case of a stitch bond.

6.2.2.2 Method B: Wire pull (applied to two bonds simultaneously)

A hook should be inserted under the lead wire connecting the die or substrate to the terminal, and a pull applied to the hook with the device clamped. The pulling force is applied approximately in the middle of the wire in a direction within 5° of the normal to the die or substrate surface or normal to a straight line between the bonds.

6.2.2.3 The pulling force should be progressively increased until the wire or a bond breaks (item a) in 6.2.2.4) or until the minimum force has been reached (item b) in 6.2.2.4).

6.2.2.4 Failure criteria

- a) For determining acceptance, the value of the pulling force at which the wire or bond breaks should be recorded and compared with that given in table 8 (see note).

For wire diameters not specified in table 8, the curves of figure 3 should be used to determine the bond pull limit. The curves are only applicable to bond pulls normal to the die.

- b) As an alternative procedure, the pulling force is increased to the specified minimum value (see note). If neither the wire nor the bond is broken, the bond is considered to have passed the test.

NOTE The pulling force should be modified where relevant (for example, for method B) by using the information given in the annex.

6.2.2.5 Classification of failures

When specified, broken wires or bonds should be classified as follows:

- a) wire break at neckdown point (reduction of section due to bonding process);
- b) wire break at a point other than neckdown;
- c) failure in bond (interface between wire and metallization) at the die;
- d) failure in bond (interface between wire and metallization) at substrate, package post or any point other than at the die;
- e) metallization lifted from the die;
- f) metallization lifted from the substrate or package post;
- g) fracture of the die;
- h) fracture of the substrate.

NOTE Method B is not recommended for the purpose of measuring the absolute value of the bond strength (see annex A). However, it may be used for testing the bond quality on a comparative basis during the manufacturing process.

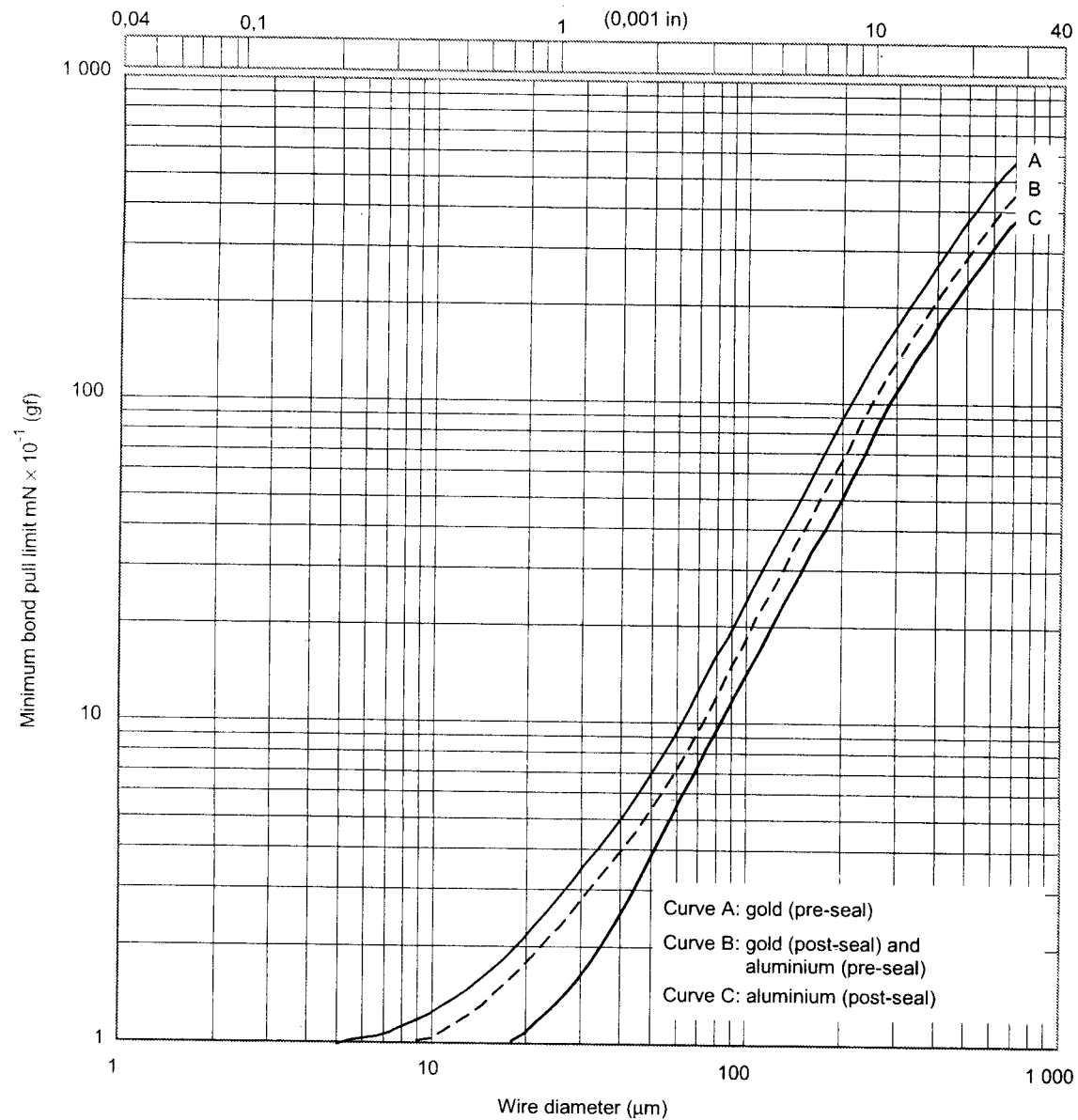
Table 8

Test method	Wire composition and diameter mm	Minimum pulling force P_w * mN			
		Pre-seal		Post-seal and any other processing or screening when applicable	
		Normal to die	Parallel to die	Normal to die	Parallel to die
A or B	Al 0,018	15	25	10	20
	Au 0,018	20	30	15	25
A or B	Al 0,025	25	35	15	25
	Au 0,025	30	40	25	35
A or B	Al 0,033	30	40	20	30
	Au 0,033	40	50	30	40
A or B	Al 0,038	35	45	25	35
	Au 0,038	50	60	35	45
A or B	Al 0,075	120	130	80	90
	Au 0,075	150	160	120	130

* See figure A.1 in annex A.

NOTE 1 For ribbon wire, use the equivalent round wire diameter that gives the same cross-sectional area as the ribbon wire being tested.

NOTE 2 Care should be taken not to damage the bond when opening the case for the post-seal tests.



NOTE The minimum pulling force should be taken from table 8. This graph may be used for wire diameters not specified in the table.

Figure 3 – Minimum bond pull limits (normal to die)

6.3 Method C

6.3.1 Scope

This test is normally intended to be applied to bonds external to the device package.

6.3.2 Method C: Bond peel

The lead or terminal and the device package should be gripped or clamped in such a manner that a peeling stress is exerted with the specified angle between the lead or terminal and the board or substrate. Unless otherwise specified, an angle of 90° should be used.

6.3.3 The pulling force should be progressively applied until the lead (or terminal) or the bond breaks (see 6.3.4.1) or until the minimum force has been reached (see 6.3.4.2).

6.3.4 Failure criteria

6.3.4.1 For determining acceptance, the value of the pulling force at which the bond breaks should be recorded and compared with that given in table 8. For wire diameters not specified in table 8, the curves of figure 3 should be used to determine the bond pull limit. The curves are only applicable to bond pulls normal to the die. The result of the test is valid only if the bond itself is the first to fail when the pulling force is applied. Only instances in which the bond itself breaks shall be counted as failures.

6.3.4.2 As an alternative procedure, the pulling force is increased to the specified minimum value. If neither the lead (or terminal) nor the bond is broken, the bond is considered to have passed the test.

6.3.5 Classification of failures

When specified, broken leads (or terminals) or bonds should be classified as follows:

- a) lead (or terminal) break at a deformation point (weld affected region);
- b) lead (or terminal) break at a point not affected by the bonding process;
- c) failure in the bond interface (in the solder, or at a point of weld interface between the lead (or terminal) and the board or the substrate conductor to which the bond was made);
- d) conductor lifted from the board or substrate;
- e) fracture within the board or substrate.

6.4 Method D

6.4.1 Scope

This test is normally intended to be applied to internal bonds between a semiconductor die and a substrate to which it is attached in a face-bonded configuration. It may also be used to test the bonds between a substrate and an intermediate carrier or secondary substrate on which the die is mounted.

6.4.2 Method D: Bond shear (applied to flip chip)

A suitable tool or wedge should be brought in contact with the die (or carrier) at a point just above the primary substrate and a force applied perpendicular to one edge of the die (or carrier) and parallel to the primary substrate, to cause bond failure by shear.

6.4.3 The force should be progressively increased until the bonds break (see 6.4.4.1) or until the minimum force (see 6.4.4.2) has been reached.

6.4.4 Failure criteria

6.4.4.1 For determining acceptance, the value of the force at which the bonds break should be recorded. It should be not less than 50 mN multiplied by the number of bonds. The result of the test is valid only if the bonds themselves are the first to fail when the force is applied. Only instances in which the bond itself breaks shall be counted as failures.

6.4.4.2 As an alternative procedure, the force is increased to 50 mN multiplied by the number of bonds. If neither the bonds nor the substrate or die are broken, the bonds are considered to have passed the test.

6.4.5 Classification of failures

When specified, the failures should be classified as follows:

- a) failure in the bond material, or bonding pedestal, where applicable;
- b) fracture in the die (or carrier) or substrate (that is, removal of a portion of the die or substrate immediately under the bond);
- c) lifted metallization (that is, separation of the metallization or bonding pedestal from the die [or carrier] or substrate).

6.5 Methods E and F

6.5.1 Scope

These tests are intended for application to beam-lead devices.

Method E is normally intended to be applied to process control and is used on a sample of semiconductor die bonded to a specially prepared substrate. Therefore, it cannot be used for random sampling of production or inspection lots.

Method F is normally intended to be applied to a sample basis on beam-lead devices that have been bonded to a ceramic or other suitable substrate.

6.5.2 Method E: Push-off test

A metallized substrate containing a hole should be employed. The hole, appropriately centred, should be sufficiently large to provide clearance for a push tool, but not large enough to interfere with the bonding areas. The push tool should be sufficiently large to minimize device cracking during testing, but not large enough to contact the beam-leads in the anchor bond area.

The substrate should be rigidly held and the push tool inserted through the hole. The contact of the push tool to the device should be made without appreciable impact (less than 0,25 mm per minute). The tool is forced against the underside of the bonded device at a constant rate until the force specified in 6.5.5 below is attained or a failure occurs.

6.5.3 Method F: Pull-off test

The calibrated pull-off apparatus should include a pull-off tool (for instance, an electrically heated loop of nichrome wire) to make connection with a hard setting adhesive material (for instance, a heat-sensitive polyvinyl acetate resin glue) on the top side of the beam-lead die. Care should be taken to ensure that no adhesive flows down to the beam or under the die. The substrate should be rigidly installed in the pull-off fixture and the pull-off tool should make firm mechanical connection to the adhesive material. The pulling force should be applied to the device within 5° of the normal and its value increased to at least that specified in 6.5.5 or until the upper surface of the die is at approximately 2,5 mm above the substrate.

6.5.4 Failure criteria for both methods E and F:

- a) broken semiconductor die;
- b) beam lifting at a bond;
- c) beam broken at a bond;
- d) beam broken at the edge of the semiconductor die;
- e) beam broken between a bond and the edge of the semiconductor die;
- f) bond lifting from the substrate;
- g) metallization lifting (separation of the metallization from either the die or a bonding pad).

6.5.5 Force to be applied (both methods)

500 mN per linear millimetre of nominal undeformed (before bonding) beam width. The bond strength should be determined by dividing the breaking force by the total of the nominal beam widths before bonding.

6.6 Method G: Wire ball shear test

6.6.1 Scope

Method G is intended to test the mechanical resistance of wire bonds to a shear force. It is recommended that it be used in addition to method A or B. It provides more information about the robustness of the metallurgical bond since, as opposed to method A or B, it has the advantage of concentrating on the bond itself rather than showing failures which are not directly linked with the quality of the bond (like wire breaking at the heel, neck, or in the span).

This method provides a standard procedure for determining the shear strength of a series of ball bonds made by either thermal compression or thermosonic techniques.

6.6.2 General description

Bond shear is a process in which an instrument uses a chisel-shaped tool to shear or push a ball or wedge bond off the bond pad (see figure 4). The force required to cause this separation is recorded and is referred to as the bond shear force. The bond shear force of a gold ball bond, when correlated to the diameter of the ball bond shear strength, is an indicator of the quality of the metallurgical bond between the gold ball bond and the bond pad metallization, as indicated in figure 5 and table 9. The bond shear force of an aluminum wedge bond, when compared to the manufacturer's tensile strength of the wire, is an indicator of the integrity of the weld between the aluminum wire and the bond pad metallization.

The ball bond includes the enlarged spherical or nail-head portion of the wire (provided by the flame-off and first bonding operation in the thermal compression or thermosonic process, or both), the underlying bonding pad and the ball bond bonding pad interfacial attachment area or weld interface.

These test methods cover ball bonds made with small diameter wire (from 18 μm to 76 μm (0,0007 in to 0,003 in)) of the type used in integrated circuits and hybrid microelectronic assemblies. These test methods can be used only when the ball height and diameter are large enough and adjacent interfering structures are far enough away to allow suitable placement and clearance (above the bonding pad and between adjacent bonds) of the shear test ram.

The test methods are destructive. They are appropriate for use in process development or, with a proper sampling plan, for process control or quality assurance.

6.6.3 Terms and definitions

6.6.3.1 Definition of shear modes (see figure 4)

6.6.3.1.1 Mode 1 – Ball lift

Separation of the whole ball bond from the bond pad with only an imprint being left on the bond pad. No intermetallic formation is evident and little, if any, disturbance of the metallization is seen.

6.6.3.1.2 Mode 2 – Bond shear/Ball shear/Wedge shear

Separation of the ball above the intermetallics. The intermetallics portion of the ball is left on the bond pad metallization along with some gold.

6.6.3.1.3 Mode 3 – Bond pad lift

Separation between the bond pad metallization and the underlying substrate. Some bond pad metallization and intermetallics remain on the ball.

6.6.3.1.4 Mode 4 – Cratering (chip-out)

Bond pad lifts, removing a portion of the substrate. Bond pad metallization and a portion of the substrate are attached to the ball.

6.6.3.1.5 Mode 5a – Instrument/operator error (shear tool too high)

Condition where the shear tool removes only the topmost part of the ball or wedge bond. Improper placement of sample, shear height too high, or malfunction of instrument.

6.6.3.1.6 Mode 5b – Instrument/operator error (shear tool too low)

The shear tool contacts the metallization or protective overcoat, producing an invalid shear value. Improper placement of sample, shear height too low, or instrument malfunction.

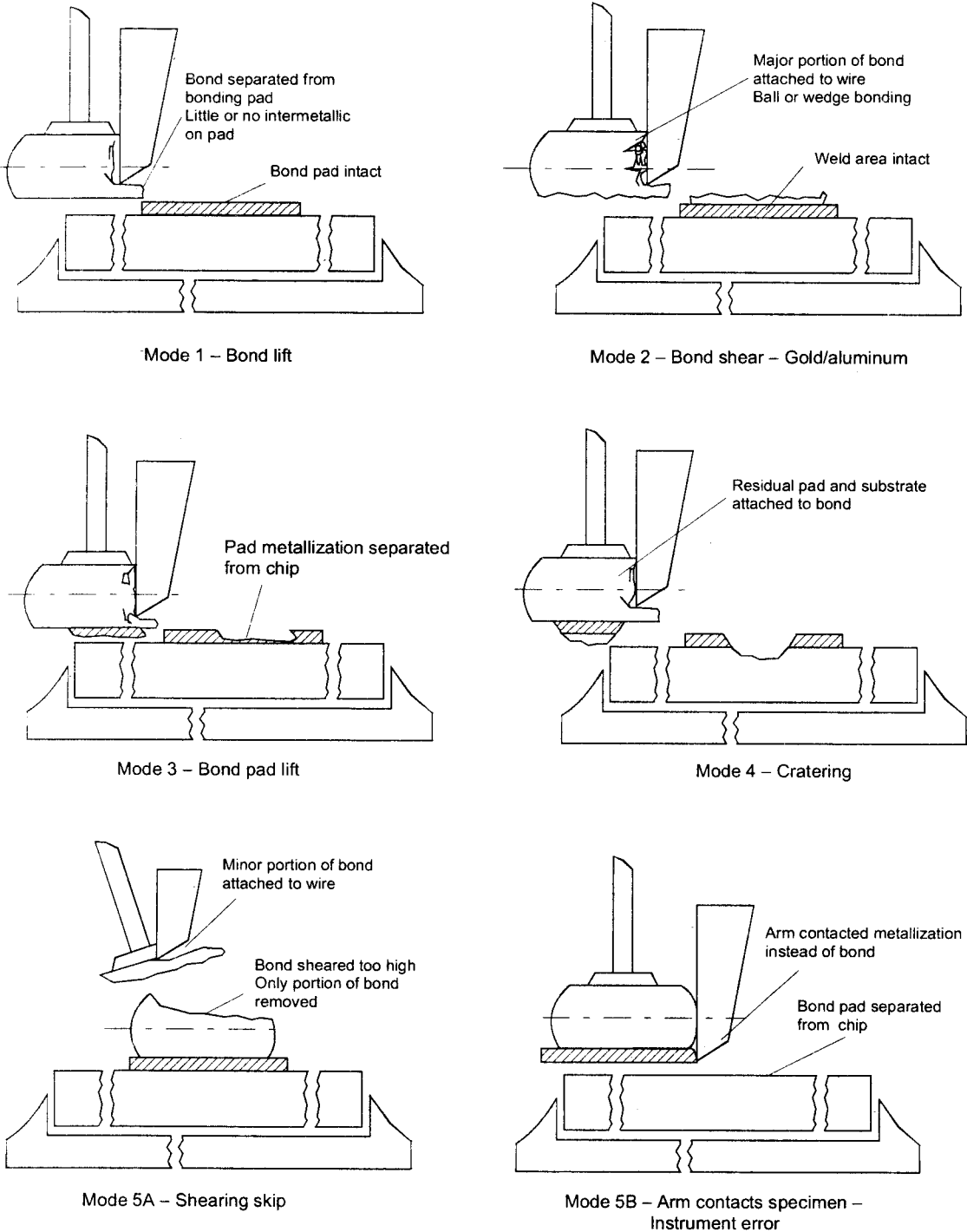


Figure 4 – Bond shear codes

6.6.3.2 Shear tool or arm

Tungsten carbide chisel, or equivalent, with specific angles on the bottom and back of the tool to assure a shearing action. Required shear tool parameters include, but are not limited to, flat shear face, sharp shearing edge, shearing width of 1,5 to 2 times the bond diameter or bond length.

The shearing tool should be designed so as to prevent ploughing and drag during testing. The tool should be clean and free of chips or other defects that will interfere with the shearing test.

6.6.3.3 Thermosonic gold (Au) ball bond

Gold ball bond formed using a thermosonic wire bond process.

6.6.3.4 Ultrasonic aluminum (Al) wedge bond

Aluminum wedge bond or weld formed using an ultrasonic wire bonding process.

6.6.4 Equipment and material

6.6.4.1 Ball shear testing shall only be conducted using equipment having the capabilities listed below.

- a) Ball bond shear tester capable of precise placement of shearing ram ($\pm 2,54 \mu\text{m}$ or $\pm 0,10 \text{ mil}$) above the substrate, fitted with zoom microscope ($70\times$ minimum magnification).
- b) Shearing tool designed so as to prevent ploughing and drag during testing. The tool should be clean and free of chips or other defects that will interfere with the shearing test.
- c) Device holder for holding the device securely at horizontal level and perpendicular to the shear tool during testing. The sample holder shall have adequate clamping capability during the test to secure the holder and the sample.
- d) The bond shear equipment shall be capable of precision placement of the shearing tool ($\pm 2,54 \mu\text{m}$ or $\pm 0,10 \text{ mil}$) above the substrate. The specified distance above the topmost part of the bonding surface shall insure the shear tool does not contact the surface of the die and shall be less than the distance from the topmost part of the bonding surface to the centre line of the ball or wedge bond.
- e) An optical microscope/measurement system capable of measuring the bond diameter to within $\pm 2,5 \mu\text{m}$ or $\pm 0,1 \text{ mil}$.

6.6.4.2 Calibration

Before performing the bond shear test, it must be determined that the equipment has been calibrated in accordance with the manufacturer's specification and is presently in calibration. Recalibration is required if the tester is moved to another location.

6.6.5 Procedure

6.6.5.1 Sample size shall be a minimum specified by SPC controls for specific devices. Normal sample size for process development should be a minimum of 50 random shears unless otherwise specified.

6.6.5.2 This test should only be used on unmoulded samples with ball heights ($\geq 10,16 \mu\text{m}$ or $\geq 0,4 \text{ mil}$) and ball spacings sufficient to allow complete and unobstructed shearing of the ball bond.

6.6.5.3 Set up the test equipment according to manufacturer's instructions. Inspect shear tool and replace tool if any damage is detected.

6.6.5.4 Place a test sample in the device holder in a level horizontal position perpendicular to the shear tool.

6.6.5.5 Position the shear tool close to the ball (within two ball diameters) and less than one-half ball height above and perpendicular to the device surface, as illustrated in modes 1 to 4 of figure 4.

The bottom of the shearing tool should be maintained below the centre line of the ball and just above the die pad metallization.

6.6.5.6 Activate the test button and allow the shear tool to move into the ball until the ball is sheared or separates from the substrate.

6.6.5.7 Examine the sheared area, record both the shear mode (as defined in 6.6.3.1) and the gram force required to shear the ball.

6.6.5.8 Repeat the test (6.6.5.3 to 6.6.5.7) for each test sample in the lot.

6.6.5.9 Calculate and record for each sample:

- a) average shear force (gf)¹⁾;
- b) minimum (gf);
- c) maximum (gf);
- d) standard deviation.

6.6.5.10 Tests determined to have interference during shear should not be included for determining the average shear value. These include wire shear, improper placement of ram (does not contact entire ball), and other tests which have interference during shear, for example: modes 5a and 5b.

6.6.5.11 Using the known (or measured) ball diameter for each test sample, calculate the average and minimum bond shear strength for each lot tested (average grams force/known average ball size).

¹⁾ Reference is being made here to grams force (gf) instead of SI units since it is common practice to use grams force in this kind of test. The formula to convert the grams force into Newtons is provided in the relevant tables and diagrams.

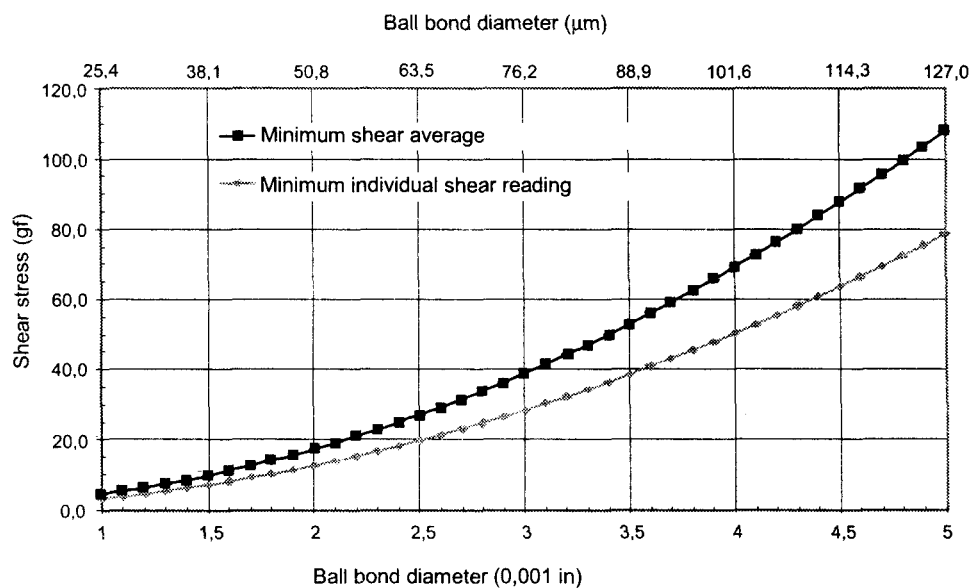
6.6.6 Acceptable test limits

6.6.6.1 Acceptable test limits for ball bonds

The ball bonds on a part shall be considered acceptable if the minimum individual and average bond shear values are greater than or equal to those stated in figure 5 and table 9.

Alternate minimum bond shear values may be used if agreed to by both the part supplier and the end-user (customer).

MINIMUM SHEAR VALUES



NOTE See table 9 for exact bond shear values.

(1 gf = 9,81 mN, 0,001 in = 25,4 μm)

Figure 5 – Minimum acceptable individual and average ball bond shear values

Table 9 – Minimum acceptable individual and average ball bond shear values for gold ball bond on A1/A1 alloy metallization

Ball diameter		Minimum shear average ¹⁾	Minimum individual shear reading ²⁾
μm	0,001 in	gf (1 gf = 9,82 mN)	gf (1 gf = 9,82 mN)
25,4	1	4,3	3,1
27,9	1,1	5,2	3,8
30,5	1,2	6,2	4,5
33,0	1,3	7,3	5,3
35,6	1,4	8,5	6,2
38,1	1,5	9,7	7,1
40,6	1,6	11,1	8,0
43,2	1,7	12,5	9,1
45,7	1,8	14,0	10,2
48,3	1,9	15,6	11,3
50,8	2	17,3	12,6
53,3	2,1	19,0	13,9
55,9	2,2	20,9	15,2
58,4	2,3	22,9	16,6
61,0	2,4	24,9	18,1
63,5	2,5	27,0	19,6
66,0	2,6	29,2	21,2
68,6	2,7	31,5	22,9
71,1	2,8	33,9	24,6
73,7	2,9	36,3	26,4
76,2	3	38,9	28,3
78,7	3,1	41,5	30,2
81,3	3,2	44,2	32,2
83,8	3,3	47,0	34,2
86,4	3,4	49,9	36,3
88,9	3,5	52,9	38,5
91,4	3,6	56,0	40,7
94,0	3,7	59,1	43,0
96,5	3,8	62,4	45,4
99,1	3,9	65,7	47,8
101,6	4	69,1	50,3
104,1	4,1	72,6	52,8
106,7	4,2	76,2	55,4
109,2	4,3	79,9	58,1
111,8	4,4	83,6	60,8
114,3	4,5	87,5	63,6
116,8	4,6	91,4	66,5
119,4	4,7	95,4	69,4
121,9	4,8	99,5	72,4
124,5	4,9	103,7	75,4
127,0	5	108,0	78,5

¹⁾ Average based on 5,5 gf/(0,001 in)² which is approximately 0,00853 gf/μm² (0,0837 mN/μm²)

²⁾ Individual minimum based on 4,0 gf/(0,001 in)² which is approximately 0,0062 gf/μm² (0,0608 mN/μm²)

6.6.6.2 Acceptable test limits for aluminium wedge bonds

The wedge bonds on a part shall be considered acceptable if the minimum shear values are equal to or greater than the manufacturer's tensile strength of the bond wire.

6.7 Information to be given in the relevant specification

When this test is required in a relevant specification, the following details should be given as far as they are applicable:

- test method;
- testing procedure: force to rupture or predetermined value of the applied force;
- minimum bond strength;
- number and selection of bonds to be tested on each device and number of devices;
- for test method C, angle of the bond peel if other than 90° and corresponding minimum bond strength.

7 Die shear strength test

7.1 Object

The object of the die shear strength test is to determine the integrity of materials and procedures used to attach semiconductor dies or passive elements to package headers or other substrates.

NOTE This determination is based on a measure of the force applied to the die or to the element, and, if a failure occurs, the type of failure resulting from the application of force and the visual appearance of the residual die attach media and the header/substrate metallization. This method is not applicable for die areas greater than 10 mm².

7.2 Description of the test apparatus

The apparatus for this test shall consist of a load applying instrument in the form of a linear motion force-applying instrument or a circular dynamometer with a lever arm. In addition it shall have the following:

- a) a contact tool which applies a uniform load to the edge of the die, perpendicular to the die mounting plane of the package or substrate (see figure 8). A compliant material on the contact tool may be used to ensure that the load is applied uniformly (see figure 6);
- b) an accuracy of 5 % of full scale or $\pm 0,5$ N whichever is the greater tolerance;
- c) a means of indicating the load applied;
- d) a facility, fitted with suitable light source, to allow visual observation (e.g. at 10 $\times$ magnification) of the die and contact tool during testing;
- e) a fixture with rotational capability relative to the die contact tool and package/substrate holding fixture to allow line contact of the tool along the whole edge of the die from end to end (see figure 7).

7.3 Test method

A force sufficient to shear the die from its mounting or equal to twice the minimum specified shear strength (see 7.4), whichever is the smaller, shall be applied to the die using the apparatus of 7.2 above with the following provisions.

- a) When a linear motion force-applying instrument is used, the direction of the applied force shall be parallel with the plane of the header or substrate and perpendicular to the die being tested.
- b) When a circular dynamometer with a lever arm is employed to apply the force required for testing, it shall be pivoted about the lever arm axis and the motion shall be parallel with the plane of the header or substrate and perpendicular to the edge of the die being tested. The contact tooling attached to the lever arm shall be at a proper distance to ensure an accurate value of applied force.
- c) The die contact tool shall load against an edge of the die which most closely approximates a 90° angle with the base of the header or substrate to which it is bonded (see figure 8).
- d) After initial contact with the die edge and during the application of force, the contact tool shall not move vertically with respect to the die such that contact is made with the header/substrate or die attach media. If the tool rides over the die, a new die may be substituted or the die may be repositioned, provided that the requirements of item c) in 7.3 are met.

7.4 Failure criteria

The strength of attachment of a die shall be considered to have failed the test if any of the following criteria exists:

- a) Unless otherwise specified in the relevant specification, die separation at a force not greater than the following:
 - 1) $4,1 \text{ mm}^2 \leq \text{die area} \leq 10 \text{ mm}^2$: 25 N;
 - 2) $\text{die area} < 4,1 \text{ mm}^2$: 6,1 N per mm^2 of die area;
 - 3) $\text{die area} > 10 \text{ mm}^2$: Not applicable (see 7.1);
- b) die separation at a force less than 1,25 times that in a) above and evidence of less than 50 % adhesion of the die attach medium to the die;
- c) die separation at a force less than 2 times that in a) above and evidence of less than 10 % adhesion of the die attach medium to the die.

NOTE Residual die material attached in discrete areas of the die attach medium should be considered as evidence of such adhesion.

7.5 Requirements

When specified, the force required to achieve separation and the category of the separation shall be recorded.

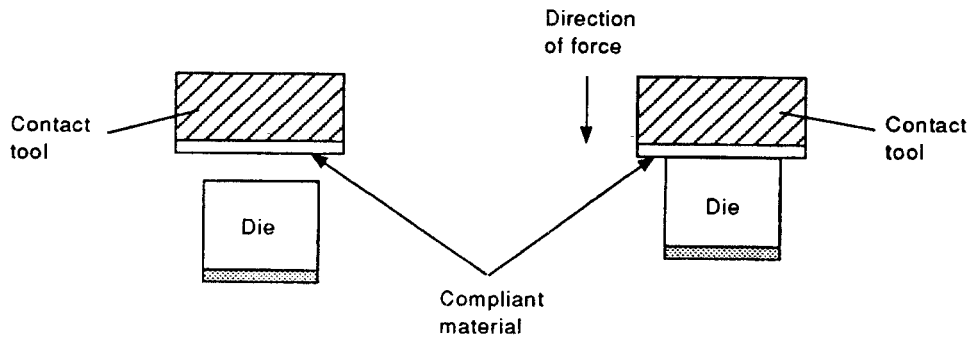
7.5.1 Categories of separation

- a) Shearing of die with residual die material remaining.
- b) Separation of die from die attach medium.
- c) Separation of die and die attach medium from package.

7.6 Information to be given in the relevant specification

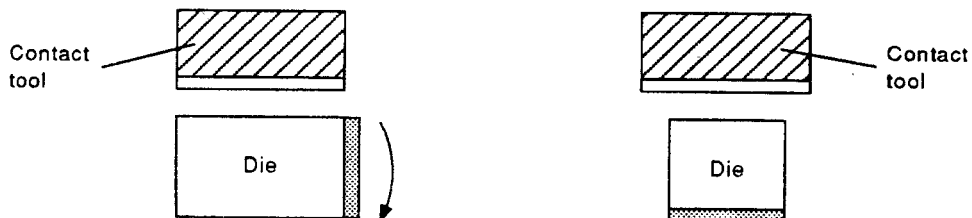
When this test is required in the relevant specification, the following details shall be given:

- minimum die attach strength if other than that given by the expressions in item a) of 7.4;
- number of devices to be tested and acceptance criteria;
- requirements for data recording, when applicable (see 7.5).



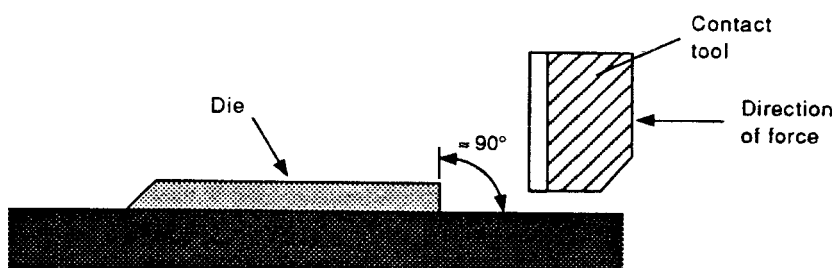
NOTE A compliant interface on the contact tool distributes the load to the irregular edge of the die.

Figure 6 – Compliant interface on contact tool (plane view)



NOTE The die contact tool or the device may be rotated to ensure parallel alignment.

Figure 7 – Alignment of tool with die (plane view)



NOTE The contact tool is loaded against the edge of the die which is perpendicular to the header/substrate.

Figure 8 – Choice of die edge for application of contact tool (elevation)

CHAPTER 3: CLIMATIC TEST METHODS

The choice of the appropriate tests depends on the type of devices and of the encapsulation. The relevant specification shall state which tests are applicable.

Temperatures shall be chosen:

- for discrete devices from IEC 60747-1, chapter 4, clause 5;
- for integrated circuits from IEC 60748-1, chapter 4, clause 5.

1 Change of temperature

Reference: IEC 60068-2-14.

1.1 Rapid change of temperature: two-chamber method

This test shall be in accordance with Test Na, with the following specific requirements:

- the use of a single test chamber that meets the specified conditions is permissible;
- the capacity of each chamber and the loading should be such that the specified exposure temperature will be reached within 2 min after the specimens are introduced into the chamber;
- the thermal time constant of the test specimen and its carrier shall be taken into account;
- low-temperature T_A : the minimum storage temperature of the semiconductor device*;
- high temperature T_B : the maximum storage temperature of the semiconductor device*;
- duration of the exposure t_1 : 10 min if the exposure temperature has been reached by the specimen within 3 min, or 10 min after thermal equilibrium of the specimen has been reached in other cases. Thermal equilibrium of the specimen shall be reached, in any case, in not more than 20 min;
- the use of automatic equipment is permitted, in which case the transition time t_2 shall be less than 1 min; otherwise the standard transition time (2 min to 3 min) shall apply;
- initial measurements:
 - mechanical tests: none,
 - electrical tests: as given in the relevant specification;
- final measurements:
 - electrical tests to be the same as for endurance tests, and an external visual examination is to be performed for evidence of cracks, breaks, loose parts.

* The tolerances for these temperatures should be such that the rated values are not exceeded.

1.2 Rapid change of temperature: two-fluid-bath method

This test shall be in accordance with Test Nc, with the following specific requirements:

Preferred temperatures (appropriate liquids for the temperature range should be chosen):

- 0 °C/+100 °C
- 55 °C/+125 °C
- 65 °C/+150 °C
- 65 °C/+200 °C
- $T_{\text{stgmin}}/T_{\text{stgmax}}$

2 Storage (at high temperature)

Reference: IEC 60068-2-48.

The specimens shall be stored at the maximum storage temperature (T_{stgmax}) as given in the relevant specification. Unless otherwise specified in the relevant specification, the duration of the test shall be selected from those given in IEC 60747-1, chapter VII, section three, subclause 2.2.1, for discrete devices and, for integrated circuits, in IEC 60748-1, chapter VII, section three, subclause 2.2.1.

After the test, the measurements specified in the relevant specification shall be performed.

3 Low air pressure

Reference: IEC 60068-2-13.

This test shall be in accordance with Test M, with the following specific requirements:

Unless otherwise specified, this test applies only to devices with operating voltages greater than 1 000 V.

- a) pre-conditioning: none;
- b) initial measurements: as specified in the relevant specification;
- c) the specified maximum voltage shall be applied to specified terminals from the start of the test (that is, before pressure reduction starts);
- d) pressure: 1 kPa (10 mbar), 4,4 kPa (44 mbar) or 60 kPa (600 mbar); duration: 1 min;
- e) not applicable;
- f) during the test, additional leakage current caused by partial breakdown shall be monitored. Visual examination may give additional information;
- g) recovery: 1 h to 2 h at standard atmospheric conditions for testing (see chapter I, clause 4 in this publication);
- h) final measurements, as specified in the relevant specification.

4A Damp heat, steady state

Reference: IEC 60068-2-3.

This test shall be in accordance with Test Ca, with the following specific requirements:

4A.1 Amend clause 1 of Test Ca to read:

1. **Object:** To assess, using unsaturated damp heat, the external aspect (such as surface finish) of semiconductor devices.

4A.2 Amend clause 6 of Test Ca to read:

6 Information to be given in the detail specification

- a) Pre-conditioning procedure: none.
- b) Checks to be made prior to the test:
 - mechanical tests: none;
 - electrical tests: none;
 - visual examination.
- c) Prior to the introduction of the device into the chamber, the device shall be heated to a temperature greater than that of the chamber, so as to avoid condensation on the device; as an alternative, the chamber may be brought to ambient temperature prior to introduction of devices into it.
- d) Severities: 10, 21 or 56 days: 21 and 56 days to be preferred.
- e) Loading (electrical operation) during conditioning: none.
- f) Electrical and mechanical checks to be made during conditioning and the period(s) after which they should be performed: none.
- g) Special precautions regarding the removal of surface moisture, if applicable.
- h) Recovery: upon completion of the conditioning, and prior to the final measurements, the specimens shall be subjected to standard atmospheric conditions for testing (see chapter 1, clause 4) for no less than 1 h and no more than 2 h, unless otherwise stated in the detail specification.
- i) Checks to be made after recovery: electrical tests as called for in the detail specification are to be performed within 24 h. When stated in the detail specification, visual examination for corrosion and legibility of marking is to be performed.

NOTE 1 This test should not be used to assess the internal aspect of semiconductor devices.

NOTE 2 The vapour pressure associated with this test is of the order of 70 hPa.

4B Damp heat, steady state, accelerated

4B.1 Object

This steady-state damp heat test is performed to assess, in an accelerated manner, the resistance of non-cavity or epoxy-sealed cavity devices to the degradation due to damp heat and to assess the effect of damp heat when combined with bias. This test is not intended to assess external effects of corrosion.

NOTE Non-cavity device: see definition in chapter I, clause 1 of this standard.

4B.2 General description

This test subjects the specimens to high levels of unsaturated damp heat for periods of 168 h to 1 000 h, depending on the severity. If specified, bias voltage is applied.

Degradation results from absorption of water vapour by the encapsulation materials and presence of moisture films or penetration of moisture along physical junctions.

4B.3 Testing chamber

The chamber shall be so constructed that:

- the temperature and humidity of the chamber are monitored by means of sensing devices located in the working space;
- the temperature and relative humidity in the working space are uniform and maintained at ± 2 °C of the specified temperature and ± 5 % of the specified relative humidity;

NOTE The temperature tolerance of ± 2 °C is intended to take account of absolute errors in the measurement, slow changes of temperature and temperature variations of the working space. It is necessary to keep short term fluctuation within $\pm 0,5$ °C to maintain the required humidity.

- condensed water is continuously drained from the chamber and not used again until it has been repurified;
- condensed water cannot fall on the specimens.

The supply water shall have a resistivity not less than 500 Ωm .

4B.4 Severities

Table 10

Test conditions (see note)		Duration				
Temperature	Relative humidity	Severity 1	Severity 2	Severity 3	Severity 4	Severity 5
85 ± 2 °C	85 ± 5 %	$168 \text{ h} \pm 16 \text{ h}$	$504 \text{ h} \pm 48 \text{ h}$	$1000 \text{ h} \pm 96 \text{ h}$	$2000 \text{ h} \pm 192 \text{ h}$	$5000 \text{ h} \pm 432 \text{ h}$
NOTE The resulting vapour pressure is of the order of 500 hPa.						

4B.5 Bias voltage

- a) When specified, the specimen shall have a voltage bias applied during exposure. Guidelines for determining the appropriate circuit configuration for bias applications are listed below in descending order of importance (see note):
- power as small as possible;
 - voltage as high as possible within the operating range;
 - voltage difference as high as possible between adjacent metallization lines on the die (for example, in the case of digital devices, adjacent inputs for the same gate would be high and low).

NOTE The highest stress conditions correspond to zero power, maximum allowed voltage to the device within the operating range and maximum allowed voltage between adjacent metallization lines on the die.

Where the dissipation of the devices cannot be reduced below 100 mW, the bias voltage shall be applied intermittently. The on-off periods shall be specified, preferably 1 h on and 3 h off.

- b) Bias voltage shall be applied to the specimens for a total time equal to the specified test duration.
The total test duration, when using intermittent bias, shall be the same (that is including on and off periods) as specified for the non-intermittent test.
- c) The voltage bias(es) shall continue to be applied to specimens until they have cooled to room temperature, unless it can be established, for the given device types and test conditions, that no significant change of characteristics occurs when the device is cooled with the bias removed.

4B.6 Testing procedure

4B.6.1 Initial measurements

Prior to exposure, the specified measurements shall be made at standard atmospheric conditions for testing or as specified.

4B.6.2 Conditioning

The specimens under test are placed at a minimum distance of 30 mm from the chamber internal surfaces and shall not be submitted to radiant heat from the heaters.

4B.6.3 Recovery

Upon completion of the conditioning, and prior to the final measurements, the specimens shall be subjected to standard conditions for testing (see chapter I, clause 4) and normal atmospheric pressure for no less than 1 h and no more than 2 h, unless otherwise stated in the detail specification.

4B.6.4 Final measurements

The specimen shall be visually inspected and electrically and mechanically checked as required in the detail specification.

Measurements may be initiated any time upon completion of the recovery period, but all measurements shall be completed within 8 h after the recovery period.

4B.7 Information to be given in the detail specification

When this test is included in the relevant specification, the following details shall be given as far as they are applicable:

	Subclause
a) Severity	4B.4
b) Bias voltage (when specified)	4B.5
c) On-off periods, if applicable	4B.5
d) Initial measurements	4B.6.1
e) Final measurements	4B.6.4

4C Damp heat, steady-state, highly accelerated

4C.1 Object

This steady-state damp heat test is performed with unsaturated and pressurized vapour to assess, in a highly accelerated manner, the resistance of non-cavity devices to the degradation due to damp heat and to assess the effect of damp heat, when combined with bias. This test is not intended to assess external effects of corrosion.

4C.2 General description

This test subjects the specimens to very high levels of unsaturated damp heat for relatively short periods. If specified, bias voltage is applied.

Test severities are determined by temperature, relative humidity and duration. Care should be taken not to reach the glass transition temperature of the encapsulating material.

Degradation results from absorption of water vapour by the encapsulation materials and presence of moisture films or penetration of moisture along physical junctions.

4C.3 Testing chamber

The chamber shall be a humidity/pressure vessel (autoclave) so constructed that:

- it can produce vapour pressures in excess of 1 000 hPa, without saturation and in conformance with the values given in subclause 4C.4;
- the temperature and humidity of the chamber are monitored by means of sensing devices appropriately located in the chamber;
- the temperature and relative humidity in the working space are uniform and maintained within the tolerances given in subclause 4C.4;
- condensed water cannot fall on the specimens;
- the water shall have a resistivity of no less than 500 Ωm .

4C.4 Severities

Table 11

Variant	Test conditions		Duration		
	Temperature	Relative humidity	Severity 1	Severity 2	Severity 3
A	110 $\pm$ 2 °C	85 $\pm$ 5 %	408 h	192 h	96 h
B	120 $\pm$ 2 °C	85 $\pm$ 5 %	192 h	96 h	48 h
C	130 $\pm$ 2 °C	85 $\pm$ 5 %	96 h	48 h	24 h
NOTE The vapour pressures are approximately 1 200 hPa, 1 700 hPa or 2 300 hPa for variants A, B and C respectively.					

4C.5 Bias voltages

- a) When specified, the specimen will have a voltage bias applied during exposure, within the operating range, taking into account safety requirements. Guidelines for determining the appropriate circuit configuration for bias application are listed below in descending order of importance (see note):

- power as small as possible;
- voltage as high as possible;
- voltage difference as high as possible between adjacent metallization lines on the die (for example, in the case of digital devices, adjacent inputs for the same gate would be HIGH and LOW).

NOTE The highest stress conditions correspond to zero power, maximum allowed voltage to the device within the operating range and maximum allowed voltage between adjacent metallization lines on the die.

- b) Where the dissipation of the specimens cannot be reduced below 100 mW, the bias voltage should be applied intermittently. The on-off periods shall be specified, preferably 1 h on and 3 h off.

- c) Bias voltage shall be applied to the specimens for a total time equal to the specified test duration.

The total test duration, when using intermittent bias, shall be the same (that is including on and off periods) as specified for the non-intermittent test.

- d) The voltage bias(es) shall continue to be applied to specimens until they have cooled to room temperature, unless it can be established, for the given device types and test conditions, that no significant change of characteristics occurs when the device is cooled with the bias removed.

4C.6 Testing procedure

4C.6.1 Initial measurements

The specimen shall be visually inspected and electrically and mechanically checked as required in the detail specification.

4C.6.2 Conditioning

- The specimens under test are placed at a minimum distance of 30 mm from the chamber internal surfaces and shall not be submitted to radiant heat from the heaters.
- The chamber is first heated to the temperature of boiling water and kept for 10 min at atmospheric pressure.
- The chamber is then heated to the required test temperature, in such a way that the water vapour remains unsaturated.
- The test duration shall be counted from the moment when pressure, humidity and temperature become stabilized. Heating and stabilization shall be achieved within 3 h.
- The bias voltage is switched on after the stabilization period.
- The sources of heat and humidity shall successively be switched off, the pressure is dropped and the specimens removed from the chamber within 2 h (see also 4C.5 d)).

4C.6.3 Recovery

Upon completion of the conditioning and prior to the final measurements, the specimens shall be subjected to standard conditions for testing (see chapter 1, clause 4) and normal atmospheric pressure for no less than 1 h and no more than 2 h, unless otherwise stated in the detail specification.

4C.6.4 Final measurements

The specimen shall be electrically and mechanically checked as required in the detail specification.

Measurements may be initiated any time upon completion of the recovery period, but all measurements shall be completed within 8 h after the recovery period.

4C.7 Information to be given in the detail specification

When the test is included in the detail specification, the following details shall be given as far as they are applicable:

	Subclause
a) Variant A, B or C	4C.4
b) Severity 1, 2 or 3	4C.4
c) Bias voltage	4C.5
d) On-off periods, if applicable	4C.5
e) Initial measurements	4C.6.1
f) Final measurements	4C.6.4

5 Sealing

5.1 General terms

5.1.1 Units of pressure

The International System of Units (SI) recommends the use of the pascal (Pa) as the unit of pressure. The commonly used units are, however, the absolute atmosphere or the bar (where 1 absolute atmosphere = 1 bar = 10^5 Pa). The unit used in this test method is the pascal with the bar used as an alternative.

5.1.2 Standard leak rate

The standard leak rate is defined as that quantity of dry air at 25 °C in pascals (bars) cubic centimeters flowing through a leak or multiple leak paths per second when the high-pressure side is at 10^5 Pa (1 bar) and the low-pressure side is at a pressure of not greater than 10^2 Pa (10^{-3} bar). The standard leak rate shall be expressed in units of pascals cubic centimetres per second (bars cubic centimetres per second).

5.1.3 Measured leak rate

The measured leak rate $R_{(He)}$ is defined as the leak rate of a given package as measured under specified conditions and employing a specified test medium. The measured leak rate shall be expressed in units of pascals cubic centimetres per second (bars cubic centimetres per second). For the purpose of comparison with rates determined by other methods of testing, the measured leak rates must be converted to equivalent standard leak rates.

5.1.4 Equivalent standard leak rate

The equivalent standard leak rate (L) of a given package, with a measured leak rate $R_{(\text{He})}$, is defined as the leak rate of the same package with the same leak geometry, that would exist under the standard conditions of 5.1.2. The formula in 5.4.3 (which does not apply to test condition 5.3) represents the L/R ratio and gives the equivalent standard leak rate (L) of the package with a measured leak rate $R_{(\text{He})}$, where the package volume and leak test conditioning parameters influence the measured value of $R_{(\text{He})}$. The equivalent standard leak rate shall be expressed in units of units of pascals cubic centimetres per second (bars cubic centimeters per second).

5.2 Bomb pressure test

Reference: IEC 60068-2-17.

This test shall be in accordance with test QI, with the following specific requirements:

- test liquid: 95 % methyl alcohol and 5 % water mixture, with addition of a detergent;
- temperature of the test liquid: $25\text{ °C} \pm 5\text{ °C}$;
- pressure: $4,5 \cdot 10^5\text{ Pa}$ (4,5 bar);
- duration of conditioning: 16 h;
- cleaning liquid: de-ionized water;
- recovery: between two days and two weeks.

NOTE The use of this test is not recommended for semiconductor devices (see annex F to IEC 60068-2-17).

5.3 Fine leak detection: radioactive krypton method

Reference: none.

5.3.1 Object

To determine the leak rate of a semiconductor device by measuring the radiation level present within the device after it has been pressurized in a chamber with suitable radioactive tracer gas.

This method is intended to be specified for devices which are designed to be hermetically sealed in glass, metal or ceramic (or combination thereof) encapsulations and is suitable for equivalent standard leak rates smaller than $1\text{ Pa}\cdot\text{cm}^3\cdot\text{s}^{-1}$ ($10^{-5}\text{ bar}\cdot\text{cm}^3\cdot\text{s}^{-1}$).

5.3.2 General description

5.3.2.1 The numerical values given are applicable for krypton 85 tracer gas and for equivalent standard leak rate limit in the order of $5 \times 10^{-3}\text{ Pa}\cdot\text{cm}^3\cdot\text{s}^{-1}$ ($5 \times 10^{-8}\text{ bar}\cdot\text{cm}^3\cdot\text{s}^{-1}$). The use of other tracer gases would require other numerical values.

5.3.2.2 Equipment

Equipment for this test consists of a radioactive tracer activation tank and a counting station with sufficient sensitivity to determine the radiation level of the tracer gas inside the device.

The equipment operates with a tracer gas mixture of dry nitrogen and krypton 85 with a specified activity (minimum: 100 $\mu\text{Ci}\cdot\text{cm}^{-3}$) under standard atmospheric conditions.

Instructions for the use of the leak testing equipment, as supplied by the manufacturer of the equipment, shall be followed in calibrating and operating the equipment. Test results obtained under non-preferred conditions can be compared with those under preferred conditions by conversion through the appropriate formula given in these instructions.

5.3.2.3 Activation parameters

The activation pressure and soak time shall be determined in accordance with the following equation (see note below).

$$Q_s = \frac{R}{skPTt} \quad (1)$$

where

- Q_s is the maximum leak rate allowable for the device to be tested, in $\text{Pa}\cdot\text{cm}^3\cdot\text{s}^{-1}$ ($\text{bar}\cdot\text{cm}^3\cdot\text{s}^{-1}$) Kr;
- R is the counts per minute above the ambient background after activation if the device leak rate were exactly equal to Q_s . This is the reject count above the background of both the counting equipment and the component if it has been through previous radioactive leak tests;
- s is the specific activity, in microcuries per cubic centimetres of the krypton 85 gas in the activation system;
- k is the overall counting efficiency of the scintillation crystal in counts per minute per one microcurie of krypton 85 in the internal cavity of the specific component being evaluated. This factor depends upon component configuration and dimensions of the scintillation crystal. The counting efficiency shall be determined in accordance with 5.3.2.4.

$$\bar{P} = P_e^2 - P_i^2,$$

where

- P_e is the absolute activation pressure in pascals (bars) and P_i is the original absolute internal pressure of the devices in pascals (bars). The activation pressure (P_e) may be established by specification, or if a convenient soak time (T) has been established, the activation pressure (P_e) can be adjusted to satisfy equation (1);
- T is the soak time that the devices are to be activated, in hours;
- t is the conversion of hours to seconds which is equal to 3 600 seconds/hour.

NOTE The complete version of equation (1) contains a factor $P_0^2 - (\Delta P)^2$ in the numerator which is a correction factor for elevation above sea-level. P_0 is the sea level absolute pressure, in pascals (bars), and ΔP is the difference in pressures, in pascals (bars), between the actual pressure at the test station and sea-level pressure. For the purposes of this test, this factor is neglected.

5.3.2.4 Determination of the counting efficiency (k)

The counting efficiency (k) of equation (1) shall be determined as follows.

- a) A representative unit of the device type to be tested shall be provided with a tube to its internal cavity and the cavity shall be backfilled through the tube with known volume and specific activity of krypton 85 tracer gas and the tubulation should be sealed off.

- b) The counts per minute in the shielded scintillation crystal of the counting station in which the devices are tested shall be directly read.

From this value, the counting efficiency in counts per minute per microcurie shall be calculated.

5.3.2.5 Evaluation of the surface sorption

For each type of encapsulation to be tested, the coatings and external sealants shall be evaluated for surface sorption of krypton 85 before establishing the leak test parameters. Representative samples of the devices shall be subjected to the predetermined pressure and time conditions established for the device configuration, as specified in 5.3.2.2 and 5.3.2.3. The count rate of the samples shall then be noted every 10 min, until it becomes constant. The elapsed time shall be noted and is the "wait time" as specified in 5.3.4.

5.3.3 Personnel precautions

Applicable national regulations for the use of radioactive gas should be followed.

NOTE Large packages with gross leaks may become excessively radioactive.

5.3.4 Procedure

The devices shall be placed in a radioactive tracer gas activation tank. The tank shall be evacuated to at least 50 Pa ($5 \cdot 10^{-4}$ bar). The actual pressure and soak time shall be determined in accordance with 5.3.2.3.

The devices shall be subjected to a minimum of $2 \cdot 10^5$ Pa (2 bar) absolute pressure of krypton 85/dry nitrogen mixture for a minimum of 12 min. The R value in counts per minute shall be not less than 600 above background. The krypton 85/dry nitrogen gas mixture shall be evacuated until a pressure less than 50 Pa ($5 \cdot 10^{-4}$ bar) exists in the activation tank. This evacuation shall be complete within a maximum of 3 min.

The activation tank shall then be backfilled with air (air wash). The devices shall then be removed from the activation tank and leak tested within 1 h after gas exposure.

The wait time determined by 5.3.2.5 shall be observed but in no case shall the time between removal from the activation chamber and test exceed 1 h.

If the test is to be repeated on the same specimen(s), then they shall first be decontaminated in a vacuum for 8 h, prior to repressurization.

The actual leak rate of the component shall be calculated using the following equation:

$$Q = \frac{(\text{actual readout in net counts per minute}) \times Q_s}{R}$$

where

Q is the actual leak rate, in $\text{Pa} \cdot \text{cm}^3 \cdot \text{s}^{-1}$ ($\text{bar} \cdot \text{cm}^3 \cdot \text{s}^{-1}$);

Q_s and R are defined in 5.3.2.3.

5.3.5 Specified conditions

Limit of the leak rate.

5.3.6 Gross leak detection

Subsequent to this test, the absence of gross leaks shall be checked by using one of the methods described in 5.5 to 5.8.

5.4 Fine leak detection: tracer gas (helium) method with mass spectrometer

Reference: IEC 60068-2-17.

This test shall be in accordance with test Qk, with the following specific requirements.

5.4.1 General

This test is applicable to cavity devices only.

Test Qk, as described in IEC 60068-2-17, is intended to be applicable to all styles of cavity packages, the mechanical robustness of which varies with size, overall wall thickness versus area ratio, material, construction, etc., and hence excludes the use of a single tracer gas pressure for the impregnation step.

The test shall be performed in accordance with IEC 60068-2-17, with the following specific requirements.

5.4.2 Method 1: specimens not filled with helium during manufacture – Fixed method

Procedure:

- a) Determine or assess the internal cavity free volume V (see note to table 12) and select the applicable range:

$<0,05 \text{ cm}^3$

$\geq 0,05 \text{ cm}^3 - \leq 0,5 \text{ cm}^3$

$\geq 0,5 \text{ cm}^3 - \leq 1,0 \text{ cm}^3$

$\geq 1,0 \text{ cm}^3 - \leq 10 \text{ cm}^3$

$\geq 10 \text{ cm}^3 - \leq 20 \text{ cm}^3$

- b) The acceptable reading on the leak rate meter is given in terms of helium leak rate $R_{(\text{He})}$.
c) The gross leak test shall be performed after the fine leak detection.

Table 12 below lists requirements covering most application cases. For other applications, the flexible method in 5.4.3 may be used. The maximum ventilation time shall be 1 h.

Table 12

Volume of package V (see note) cm ³	Pressure exposure condition		R _(He) Reject limit Pa·cm ³ ·s ⁻¹ (bar·cm ³ ·s ⁻¹)
	P _{abs} Pa (bar)	Minimum exposure time t ₁ h	
V < 0,05	5·10 ⁵ (5)	2	5·10 ⁻³ (5 × 10 ⁻⁸)
0,05 ≤ V < 0,5	5·10 ⁵ (5)	4	5·10 ⁻³ (5 × 10 ⁻⁸)
0,5 ≤ V < 1,0	3·10 ⁵ (3)	2	5·10 ⁻² (5 × 10 ⁻⁷)
1,0 ≤ V < 10,0	3·10 ⁵ (3)	5	5·10 ⁻³ (5 × 10 ⁻⁸)
10 ≤ V < 20,0	3·10 ⁵ (3)	10	5·10 ⁻³ (5 × 10 ⁻⁸)
NOTE The internal free volume is the cavity volume that can be, by design, filled with gas. Taking into account the selected ranges, a rough assessment of it is usually adequate.			

5.4.3 Method 2: specimens not filled with helium during manufacture – Flexible method

Values for pressure exposure time and ventilation time shall be chosen such that the actual measured tracer gas leak rate $R_{(He)}$ readings obtained for the devices under test (if defective) will be greater than the minimum detection sensitivity capability of the mass spectrometer. The devices shall be subjected to a minimum of 2·10⁵ Pa (2 bar) absolute of helium atmosphere. If the chosen ventilation time (t_2) is greater than 1 h, graphs shall be plotted to determine an $R_{(He)}$ value which will assure overlap with the selected gross leak test condition. The chosen values, in conjunction with the value of the internal volume of the device package to be tested and the maximum equivalent standard leak rate (L) limit (as shown below or as specified in the applicable specification), shall be used to calculate the measured leak rate ($R_{(He)}$) limit using the following formula:

$$R_{(He)} = \frac{LP_E}{P_O} \left(\frac{M_A}{M} \right)^{1/2} \left\{ 1 - e^{-\left[\frac{Lt_1}{VP_O} \left(\frac{M_A}{M} \right)^{1/2} \right]} \right\} e^{-\left[\frac{Lt_2}{VP_O} \left(\frac{M_A}{M} \right)^{1/2} \right]}$$

where

- $R_{(He)}$ is the measured leak rate of the tracer gas (He) through the leak, in (Pa·cm³He)·s⁻¹ (bar·cm³He)·s⁻¹;
- L is the equivalent standard leak rate, in Pa·cm³·s⁻¹ air (bar·cm³ air)·s⁻¹;
- P_E is the pressure of exposure, in pascals (bars);
- P_O is the atmospheric pressure, 10⁵ pascals (1 bar);
- M_A is the molecular weight of air, in grams (28,7);
- M is the molecular weight of the tracer gas (helium), in grams (4);
- t_1 is the time of exposure to P_E , in seconds;
- t_2 is the ventilation time between release of pressure and leak detection, in seconds;
- V is the internal volume of the device package cavity, in cubic centimetres.

5.4.3.1 Failure criteria

Unless otherwise specified, devices with an internal cavity volume of $0,01 \text{ cm}^3$ or less shall be rejected if the equivalent standard leak rate (L) exceeds $5 \times 10^{-3} \text{ Pa}\cdot\text{cm}^3\cdot\text{s}^{-1}$ air ($5 \times 10^{-8} \text{ bar}\cdot\text{cm}^3\cdot\text{s}^{-1}$ air). Devices with an internal cavity volume greater than $0,01 \text{ cm}^3$ and equal to or less than $0,4 \text{ cm}^3$ shall be rejected if the equivalent standard leak rate (L) exceeds $10^{-2} \text{ Pa}\cdot\text{cm}^3\cdot\text{s}^{-1}$ air ($10^{-7} \text{ bar}\cdot\text{cm}^3\cdot\text{s}^{-1}$ air). Devices with an internal cavity volume greater than $0,4 \text{ cm}^3$ shall be rejected if the equivalent standard leak rate (L) exceeds $10^{-1} \text{ Pa}\cdot\text{cm}^3\cdot\text{s}^{-1}$ air ($10^{-6} \text{ bar}\cdot\text{cm}^3\cdot\text{s}^{-1}$ air).

NOTE Failure criteria in 5.4.3.1 are given as the equivalent standard leak (air). Failure criteria in 5.4.2 (table 12) are given as measured helium leak rates.

5.4.4 Method 3: specimens filled with helium during manufacture

This test shall be performed in accordance with IEC 60068-2-17, clause E.6 of test Qk.

5.4.5 Gross leak detection

Subsequent to this test, the absence of gross leaks shall be checked by using one of the methods described in 5.5 to 5.8.

5.5 Gross leaks, perfluorocarbon vapour method using electronic detection apparatus

Reference: None.

5.5.1 Object

To determine the leak rate of a semiconductor device by measuring the amount of perfluorocarbon escaping from the device after it has been pressurized in the impregnation liquid.

This method is intended to be specified for devices which are designed to be hermetically sealed in glass, metal, or ceramic (or combination thereof) encapsulations and is suitable for equivalent standard leak rates higher than $10^{-1} \text{ Pa}\cdot\text{cm}^3\cdot\text{s}^{-1}$ ($10^{-6} \text{ bar}\cdot\text{cm}^3\cdot\text{s}^{-1}$).

This method is an alternative to the test described in IEC 60068-2-17, method Qc.

5.5.2 General description

The semiconductor devices are pressurized at specified conditions, removed from the pressure chamber, and placed in a heated cell. The heated cell is connected to a detector that is sensitive to the impregnation fluid used for the pressurization cycle. If the device has leaks, it will contain fluid that will vaporize, and the vapour is then detected by the test apparatus. The amount of vapour escaping per unit time is indicative of the leak rate. The test may also be used on a go/no-go basis for screening purposes.

5.5.3 Test apparatus

5.5.3.1 Description

Equipment for this test consists of a vacuum/pressure chamber and a perfluorocarbon vapour detector capable of detecting the presence of $0,15 \mu\text{l}$ of the detector fluid in the volume of the test cell.

The apparatus operates using an impregnation liquid having a kinematic viscosity of the order of $0,4 \times 10^{-6} \text{ m}^2\cdot\text{s}^{-1}$ (0,4 cSt) at room temperature, a boiling point between 75 °C and 85 °C and low heat of vaporization at boiling point so as to generate vapour quickly within the specimen when heated.

NOTE Commonly used liquids are perfluorocarbons. A type I fluid should be used (see table 14).

5.5.3.2 Precautions

The perfluorocarbon vapour detection apparatus shall be located at a minimum distance of 3 m from the pressurization chamber.

5.5.4 Test method

The devices shall be enclosed in a vacuum/pressure chamber and the pressure reduced to 500 Pa to 600 Pa ($5 \cdot 10^{-3}$ bar to $6 \cdot 10^{-3}$ bar) and maintained for 30 min to 45 min. A sufficient amount of impregnation fluid shall be admitted to the pressure chamber to cover the devices. The fluid shall be admitted after the vacuum period but before breaking the vacuum. The devices shall then be pressurized to $5 \cdot 10^5$ to $6 \cdot 10^5$ Pa (5 bar to 6 bar). The pressure shall be maintained for a period of 30 min to 45 min. If the devices will not withstand $5 \cdot 10^5$ Pa (5 bar) pressure, the pressure may be lowered to a minimum of $2 \cdot 10^5$ Pa (2 bar) and the pressure maintained for 2,5 h to 3 h. Upon completion of the pressurization period, the pressure shall be released, the devices removed from the pressure chamber and retained in a bath of impregnating fluid. When the devices are removed from the fluid, they may be air dried prior to the test cycle. The drying time shall be limited to 5 min maximum. The devices shall then be tested with the perfluorocarbon vapour detection system. The "preheat" time for drying the external surfaces of the device shall be in accordance with table 13. The test time shall be a minimum of 3,5 s, unless the device is rejected earlier. The preheat and test chambers shall be at a temperature of $125 \text{ °C} \pm 5 \text{ °C}$.

Table 13

Package with internal free volume cm^3	Preheat time at $125 \text{ °C} \pm 5 \text{ °C}$ s
$V \leq 0,010$	≤ 5
$0,010 < V \leq 0,4$	≤ 9
$V > 0,4$	≤ 13
NOTE Maximum preheat time can be determined by cycling a device having a 0,5 mm to 1,5 mm hole and measuring the maximum preheat time that can be used without permitting the device to escape detection.	

5.5.5 Reject criterion

Unless otherwise specified, a device that indicates a perfluorocarbon level equal to, or greater than, the level indicated by 0,15 μl of perfluorocarbon shall constitute a failure.

5.6 Gross leak – Perfluorocarbon – bubble detection method

Reference: IEC 60068-2-17.

As an alternative to methods 5.5, 5.7 and 5.8, the absence of gross leaks shall be checked by using method 2 or 3 of test Qc of IEC 60068-2-17, as required by the detail specification.

Recommended liquids for test Qc (see table 14) are as follows.

Method 2: type II fluid

Method 3: Step 1: type I fluid
Step 2: type II fluid

The following requirements shall apply.

- a) The temperature of the bath used for method 2 shall be $125\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$, unless otherwise stated in the detail specification.
- b) The immersion time in the bath used for method 2 shall be a minimum of 60 s, unless otherwise stated in the detailed specification.
- c) Observation shall be made against a dull non-reflective black background, under direct lighting adjusted to provide maximum reflectability at the specific position, through a 3× magnifier or stereo zoom microscope arranged for the observation of bubbles emanating from the specimen immersed in the liquid.

5.7 Test condition E, weight-gain gross-leak detection

5.7.1 Object

As an alternative to methods 5.5, 5.6 and 5.8, the absence of gross leaks shall be checked by the following weight-gain method.

5.7.2 Equipment

Apparatus for this test shall consist of:

- a) a vacuum/pressure chamber for the evacuation and subsequent pressure bombing of devices up to $6 \cdot 10^5$ Pa (6 bar) absolute up to 10 h;
- b) an analytical balance capable of weighing the devices accurately to 0,1 mg;
- c) a source of type III detector fluid as specified in table 14;
- d) a filtration system capable of removing particles greater than $1\text{ }\mu\text{m}$ in size from the perfluorocarbon fluid;
- e) suitable calibrated instruments to measure test pressures and times.

Table 14 – Physical property requirements of perfluorocarbon fluids^a

Property	Type I	Type II	Type III
Boiling point (°C)	50-95	140-200	50-110
Surface tension (dynes/cm) at 25 °C		<20	
Density at 25 °C (g/ml)	>1,6	>1,6	>1,6
Density at 125 °C (g/ml)		>1,5	
Dielectric strength (V/mm)	>12 000	>12 000	>12 000
Residue (mg/g)	<50	<50	<50
Appearance	Clear colourless		
a Perfluorocarbons contain no chlorine or hydrogen.			

5.7.3 Procedure

The devices shall be placed in an oven at 125 °C for 1 h minimum, after which they shall be allowed to cool to room ambient temperature. Each device shall be weighed and the initial weight recorded or the devices may be categorized into cells as follows. Devices having a volume of <0,01 cm³ shall be categorized in cells of 0,5 mg increments and devices with volume ≥0,01 cm³ shall be categorized in cells of 1,0 mg increments. The devices shall be placed in a vacuum/pressure chamber and the pressure reduced to 500 Pa (5·10⁻³ bar) and maintained for 1 h except that, for devices with an internal cavity volume ≥0,1 cm³, this vacuum cycle may be omitted. A sufficient amount of type III detector fluid shall be admitted to the pressure chamber to cover the devices. When the vacuum cycle is performed, the fluid shall be admitted after the 1 h period but before breaking the vacuum. The devices shall then be pressurized to 5·10⁵ Pa (5 bar absolute) minimum except that 6·10⁵ Pa (6 bar absolute) minimum shall be used when the vacuum cycle has been omitted. The pressure shall be maintained for 2 h minimum. If the devices will not withstand the 5·10⁵ Pa (5 bar absolute) test pressure, the pressure may be lowered to 3·10⁵ Pa (3 bar absolute) minimum with the vacuum cycle and the pressure maintained for 10 h minimum.

Upon completion of the pressurization period, the pressure shall be released and the devices removed from the pressure chamber and retained in a bath of the perfluorocarbon fluid. When the devices are removed from the fluid, they shall be air dried for 2 min ± 1 min prior to weighing. Transfer the devices singly to the balance and determine the weight or weight category of each device. All devices shall be tested within 4 min following removal from the fluid. The delta weight shall be calculated from the record of the initial weight and the post weight of the device. Devices which were categorized shall be separated into two groups, one group which shall be devices which shifted one cell or less and the other group which shall be devices which shifted more than one cell.

5.7.4 Failure criteria

A device shall be rejected if it gains 1,0 mg or more and has an internal volume of ≥0,01 cm³ and 2,0 mg or more if the volume is >0,01 cm³. If the devices are categorized, any device which gains enough weight to cause it to shift by more than one cell shall be considered a reject. A device which loses weight of an amount which, if gained, would cause the device to be rejected, may be re-tested after it is baked at 125 °C for a period of 8 h.

5.8 Penetrant dye gross leak detection

5.8.1 Equipment

The following apparatus shall be used for this test.

- a) Ultraviolet light source with peak radiation at approximately the frequency causing maximum reflection of the dye (3650 Å for Zyglo, 4935 Å for Fluorescein, 5560 Å for Rhodamine B, etc.).
- b) Pressure chamber capable of maintaining $7 \cdot 10^5$ Pa (7 bar absolute).
- c) Solution of fluorescent dye (such as Rhodamine B, Fluorescein; Dye-check, Zyglo, FL-50, or equivalent) mixed in accordance with the manufacturer's specification.
- d) A magnifier with a magnification in the range between 1,5× to 30× for dye observation.

5.8.2 This test shall be permitted only for destructive verification of devices (see 5.9). The pressure chamber shall be filled with the dye solution to a depth sufficient to completely cover all the devices. The devices shall be placed in the solution and the chamber pressurized at $7 \cdot 10^5$ Pa (7 bar absolute) minimum for 3 h minimum. For device packages which will not withstand $7 \cdot 10^5$ Pa (7 bar absolute), $4 \cdot 10^5$ Pa (4 bar absolute) minimum for 10 h may be used. The devices shall then be removed and carefully washed, using a suitable solvent for the dye used, followed by an air-jet dry. The devices shall then be immediately examined under the magnifier using an ultraviolet light source of appropriate frequency.

5.8.3 Failure criterion

Any evidence of dye penetration into the device cavity shall constitute a failure.

5.9 Gross leak re-test

Devices which fail the gross leak test (test conditions 5.5, 5.6 or 5.7) may be re-tested destructively.

If the re-test shows a device to pass, that was originally thought to be a failure, then the device need not be counted as a failure in the accept number of sample size number calculations. Devices which fail the fine-leak test (test methods 5.3 or 5.4) shall not be retested for acceptance unless specifically permitted by the applicable acquisition document. Where a fine leak re-test is permitted, the entire leak test procedure for the specified test condition shall be repeated, i.e. the re-test consisting of a second observation on leak detection without a re-exposure to the tracer fluid or gas under the specified test condition shall not be permissible in any circumstances. Preliminary measurement to detect residual tracer gas is advisable before any retest.

6 Salt mist

Reference: IEC 60068-2-11.

This test shall be in accordance with Test Ka, with the following specific requirements:

- conditioning duration: 24 h;
- recovery: the component shall be *lightly brushed* and washed in running tap-water...;
- final measurements, failure criteria:

evidence of flaking or pitting in the finish, when viewed with 3× to 10× magnification.

7 Thermal intermittence test

Reference: IEC 60068-2-14.

To determine whether the internal interconnection system of a semiconductor device is subject to intermittent failures when subjected to a slowly changing temperature. This test is primarily intended for devices having no internal cavity. It shall be in accordance with Test Nb, with the following specific requirements:

- the test chamber should include provision for electrical connection to, and monitoring of, device(s) under test with access to each device terminal;
- the cycle may be performed either from the specified low temperature to the specified high temperature, or conversely;
- the conditions indicated in table 15 shall apply.

Table 15

	Severity		
	A	B	C
Low temperature T_A	25 °C ± 5 °C	Minimum operating temperature	Minimum storage temperature
High temperature T_B	125 °C ± 5 °C	Maximum operating temperature	Maximum storage temperature
Rate of change of temperature (average over the period of temperature change (see note))	3 °C maximum/minute		
Number of cycles	1/2 (that is, from T_A to T_B or T_B to T_A)		
Duration of exposure	$t_1 \geq 1$ min		

- no initial, no final measurements;
- electrical checks during conditioning;

an example of parallel detection circuit is given in figure 9; other circuits (series detection, constant voltage generator, etc.) are also permitted.

NOTE A faster change of temperature is acceptable provided that the time constant and the scanning rate of the detector are compatible with the rate of change of temperature.

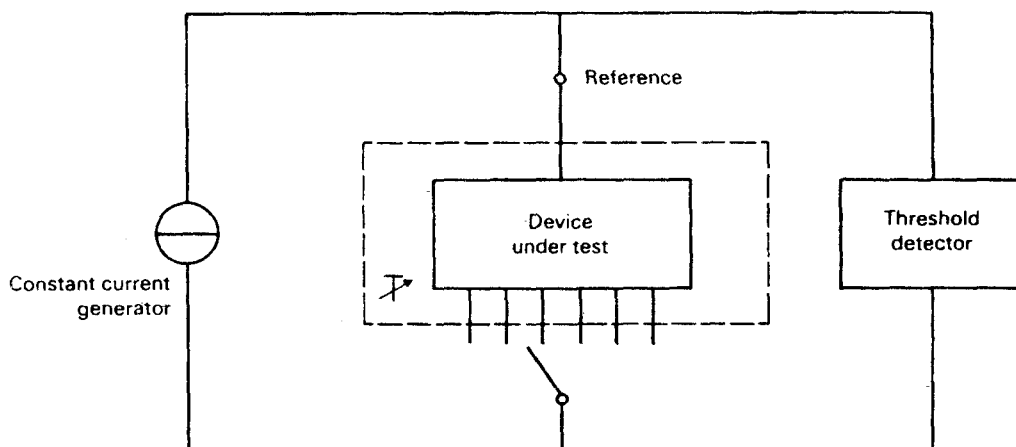


Figure 9 – Parallel detection circuit

The test apparatus should be capable of sensing and identifying a failed device.

The threshold detector should be set to indicate a failure at a voltage specified by the relevant specification.

A failure is defined by an evidence of open-circuit at any internally connected terminal or short-circuit between two leads.

After the initial change from room temperature to T_A or T_B , device terminals should be monitored at least once for each 3 °C change when the temperature is varied either from minimum to maximum or from maximum to minimum (see note above).

The test conditions used for testing the continuity of each lead should be specified so that minimum power dissipation is obtained, in order that the case and junction temperature will be approximately equal to that of the ambient temperature.

8 Internal moisture content measurement by mass spectrometry method

8.1 Object

The purpose of this destructive test is to measure the water vapour content of gas contained in a hermetically sealed package.

8.2 General description

The package to be analyzed is placed in a suitable apparatus essentially composed of a vacuum opening chamber tightly connected to a mass spectrometer.

After pumping down the chamber, the package is pierced and its gaseous content is analyzed for determination of its water vapour content.

8.3 Test apparatus

The main features of the apparatus are the following.

8.3.1 The temperature of the opening chamber shall be stabilized at $100\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$. The transfer passage (between the opening chamber and the mass spectrometer), the ion source and the analyzer chamber shall be kept continuously at $125\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$.

8.3.2 The apparatus sensitivity shall be at least ten times better than the acceptance limit specified for the package.

8.3.3 The apparatus calibration shall be performed at the specified moisture limit ($\pm 20\%$) using a package simulator which has the capability of generating at least three different volumes of gas with a tolerance of $\pm 10\%$. The moisture content shall be established by the standard generation techniques (i.e. two pressure, divided flow, or cryogenic method).

The calibration operation shall be performed:

- every day for spectrometer measurement calibration;
- every year for the absolute moisture generator (connected to the simulator) versus the national standards.

8.3.4 The piercing action shall not modify the gaseous content to be analyzed.

8.4 Preconditioning

Cleanliness precautions shall be observed at all steps. Packages to be tested shall be submitted, in the following order, to:

- sealing test (see clause 7);
- cleaning (see 10.8.3);
- prebaking for 12 h to 24 h at $125\text{ }^{\circ}\text{C}$ under a vacuum equal to or less than 10 kPa (0,1 bar).

8.5 Conditioning

The package shall be taken from the prebake chamber and immediately put into the opening chamber. The air pressure in this chamber shall then be gradually decreased. The chamber and the package shall be heated at $100\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ for a duration allowing them to reach the stabilized specified vacuum level and temperature before performing the following measurements:

- a) determination of the chamber pressure increase when the gases are released. A pressure rise of less than 50 % of normal invalidates the test;
- b) mass spectrum scanning to detect air constituents in the package;
- c) proportions (by volume) of water vapour content and other constituents if required in the relevant specification.

8.6 Requirements

A package that has a water vapour content greater than the specified maximum value shall be considered defective.

8.7 Information to be given in the relevant specification

- a) Gaseous constituents to be detected, if applicable; see item b) of 8.5.
- b) Permissible proportion of water vapour; see item c) of 8.5.
- c) Permissible proportion of other gaseous constituents, if applicable; see item c) of 8.5.

8.8 Guidance

8.8.1 General considerations

Water vapour content measurements, in the case of electronic device packages, are complicated by two characteristics.

- a) The analyzed volume is often very small (i.e. 0,01 cm³ to 0,1 cm³).
- b) The specified maximum water vapour contents are usually less than 5 000 ppm V.

8.8.2 Piercing tools

Point piercing tools used shall not disturb the specified vacuum. Sharp-pointed tools actuated from outside the chamber wall (via a bellows to permit the movement) should be used to pierce both metal and ceramic packages. In some cases, it may be necessary to reduce the thickness of the area to be pierced.

8.8.3 Recommended cleaning sequence

Five minutes ultrasonic cleaning in each of three successive baths:

- trichloroethylene;
- isopropyl alcohol;
- acetone.

(See also IEC 60653.)

CHAPTER 4: MISCELLANEOUS TEST METHODS

1 Flammability tests of plastic-encapsulated devices

1.1 Flammability (internally induced)

Reference: none.

The purpose of this test is to determine whether the device ignites due to internal heating caused by excessive overloads.

The device shall be operated in free air without a heat sink and the internal electrical power dissipation slowly increased from the maximum rated value until any of the following occurs:

- 1) an internal power dissipation equal to five times the maximum rated power dissipation at 25 °C is reached; in this case, the power shall be maintained for a minimum duration of 1 min; or
- 2) the device becomes either open-circuited or short-circuited, or its resistance increases to such a high value that any further increase in power dissipation is impracticable; or
- 3) the device ignites.

A device shall constitute a failure only if it smoulders or ignites.

1.2 Flammability (externally induced)

Reference: IEC 60695-2-2.

This test shall be in accordance with the needle-flame test, with the following specific requirements:

- a) preconditioning: none;
- b) number of test specimens: three, unless otherwise stated in the detail specification;
- c) position of the specimen: as per figure 1b of IEC 60695-2-2;
- d) surface to be tested and point of application: as per figure 1b of IEC 60695-2-2;
- e) underlying layer: paper on pinewood, as per clause 4 of IEC 60695-2-2;
- f) duration of application of the flame (t_a): 10 s;
- g) duration of burning: 10 s;
- h) extent of burning: it shall not extend over a surface significantly greater than that touched by the flame during its application.

2 Permanence of marking

Reference: IEC 60068-2-45.

This test shall be in accordance with Test XA, with the following specific requirements:

Amend clause 8 of Test XA to read:

8.1 Solvents to be used:

Type B: a mixture of R113 (70 ± 5 %), and isopropyl alcohol (30 ± 5 %)

Type C: distilled or deionized water.

8.2 Solvent temperature: 23 ± 5 °C for solvent B.
 55 ± 5 °C for solvent C.

8.3 Initial measurements: not applicable, unless otherwise required in the detail specification

8.4 Conditioning: method 1.

NOTE Unless otherwise specified, one half of the specimens shall be tested with solvent B and the other half with solvent C.

8.5 Rubbing material: cotton wool.

8.6 Recovery time: no less than 2 h and up to 24 h if final electrical measurements are required in the relevant specification, otherwise not applicable.

8.7 Final measurements: not applicable, unless otherwise required in the detail specification.

8.8 Acceptance criteria: the marking shall remain legible (other criteria may be required in the relevant specification).

Annex A (normative)

Guidance (see chapter 2, 6.2)

Method A

As a general guidance, a stitch type bond should normally be submitted to a shear force, and a nail-head type bond to withstand a pulling force.

Method B

The force that is actually applied to the bonds varies considerably with the length of the wire loop between bonds, that is, parameters A and h of figure A.1, and with the vertical distance d between bonds. If the wire loop is very short, the breaking load of the wire may easily be exceeded even if the force applied to the hook is smaller than this limit. For instance, it can be seen from the formula given below that a pulling force P_w of approximately 100 mN will be exerted on a wire when a force P of 40 mN is applied to the hook, and $h = 0,1$ mm, $A = 2$ mm and $d = 0,2$ mm. In such a case, a gold wire of 0,025 mm diameter is likely to be broken before the bond gives way. If $d = 0$, a similar pulling force will be developed with P reduced to 20 mN.

The values of pulling force normal to the die quoted in table 8 correspond to the pull (P) applied to the hook. These are the limits used in normal practice, where half the force ($P/2$) is applied normally (perpendicularly) to each bond.

Where very flat loops are used (e.g. some microwave and RF devices), the parallel-to-die figures may be used. In such cases, both h and d in figure A.1 are small compared with A and the term

$$1 + \frac{A^2}{(2h + d)^2} \text{ in the equation of figure A.1 approximates to } \frac{A^2}{(2h + d)^2}.$$

This force (P_w) is applied to both bonds simultaneously when the force P is applied to the hook and, using the approximation above, is related by

$$P_w = \frac{P}{4} \left(\frac{A}{h + d/2} \right)$$

or

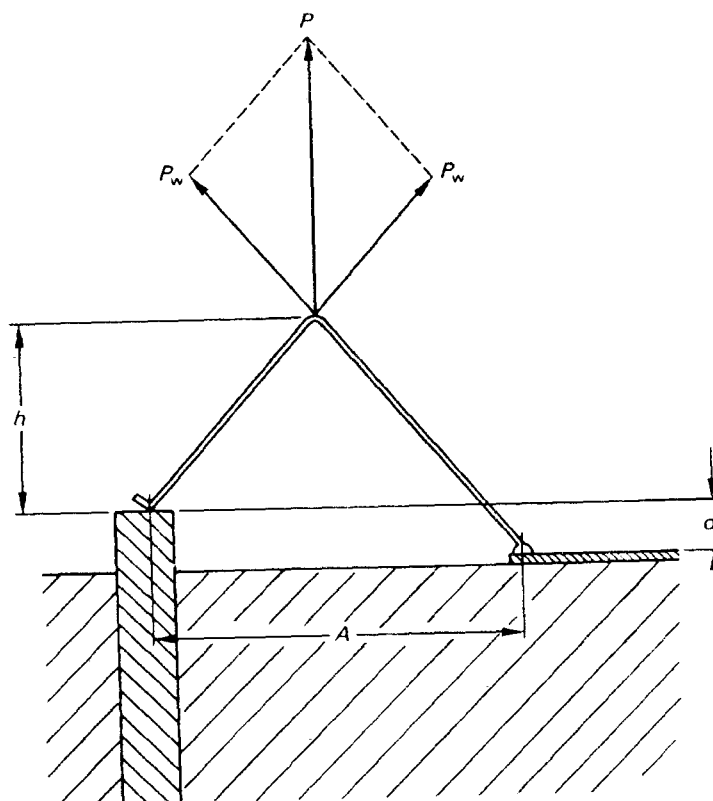
$$P = 4 P_w (h + d/2) / A$$

This can be rearranged to give the height of the loop:

$$(h + d/2) = A \frac{P}{4P_w}$$

Thus, for example, if from table 8 $P = 15$ and $P_w = 25$, then the parallel pull limit will be reached before the normal limit, if the height of the loop ($h + d/2$) is less than $15A/(4 \times 25) = 0,15A$.

Under these circumstances, the pull on the hook (P) may be reduced to give the required parallel pull applicable to the height of the loop being tested. Where individual loop height measurements are impractical, the pull (P) corresponding to the highest loop shall be used.



$$P_w = \frac{P}{2} \left[1 + \frac{A^2}{(2h + d)^2} \right]^{1/2}$$

Figure A.1

(Continued from second cover)

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
IEC 68-2-11 (1981) Environmental testing — Part 2 : Tests — Test Ka : Salt mist	IS 9000 (Part 11) : 1983 Basic environmental testing procedures for electronic and electrical items: Part 11 Salt mist test	Technically equivalent
IEC 68-2-13 (1983) Environmental testing — Part 2 : Tests — Test M : Low air pressure	IS 9000 (Part 13) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 13 Low air pressure test	do
IEC 68-2-14 (1984) Environmental testing — Part 2 : Tests — Test N : Change of temperature	IS 9000 (Part 14) : 1988 Basic environmental testing procedures for electronic and electrical items: Part 14 Test N Change of temperature	do
IEC 68-2-17 (1994) Environmental testing — Part 2 : Tests — Test Q : Sealing	IS 9000 (Part 15) : 1982 Basic environmental testing procedures for electronic and electrical items: Part 15 Sealing test	do
IEC 68-2-20 (1979) Environmental testing — Part 2 : Tests — Test T : Soldering	IS 9000 (Part 18) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 18 Solderability test	do
IEC 68-2-21 (1983) Environmental testing — Part 2 : Tests — Test U : Robustness of terminations and integral mounting devices	IS 9000 (Part 19) : 1986 Basic environmental testing procedures for electronic and electrical items: Part 19 Test U, Robustness of terminations and integral mount devices	do
IEC 68-2-45 (1980) Environmental testing — Part 2 : Tests — Test XA and guidance : Immersion in cleaning solvents	IS 9000 (Part 20) : 1979 Basic environmental testing procedures for electronic and electrical items: Part 20 Resistance to cleaning solvents and permanence of markings	do
IEC 653 (1979) General considerations on ultrasonic cleaning	IS 9001 (Part 18) : 1986 Guidance for environmental testing: Part 18 Ultrasonic cleaning test	do
IEC 695-2-2 (1991) Fire hazard testing — Part 2 : Test methods — Section 2 : Needle-flame test	IS 11000 (Part 2/Sec 2) : 1984 Fire hazard testing: Part 2 Test methods, Section 2 Needle-flame test	Identical
IEC 747-1 (1983) Semiconductor devices — Discrete devices and integrated circuits — Part 1 : General	IS 14901 (Part 1) : 2001 Semiconductor devices — Discrete devices and integrated circuits: Part 1 General	do
IEC 748-1 (1984) Semiconductor devices, Integrated circuits — Part 1 : General	IS 12970 (Part 1) : 1990 Semiconductor devices — Integrated circuits: Part 1 General	Technically equivalent

The concerned Technical Committee responsible for the preparation of this standard has reviewed the provisions of the following International Publications and has decided that they are acceptable for use in conjunction with this standard:

IEC 68-2-47 (1982) 'Environmental testing — Part 2 : Tests — Mounting of components, equipment and other articles for dynamic tests including shock (Ea), bump (Eb), vibration (Fc and Fd) and steady-state acceleration (Ga) and guidance'

IEC 68-2-48 (1982) 'Environmental testing — Part 2 : Tests — Guidance on the application of the tests of IEC Publication 68 to simulate the effects of storage'

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BUREAU OF INDIAN STANDARDS

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Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402

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Regional Offices:

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Telephone

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Eastern : 1/14 C.I.T. Scheme VII M, V.I.P. Road, Kankurgachi
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